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EXECUTIVE SUMMARY

In a 1985 survey conducted by the U.S. House of Representatives, a questionnaire was sent to 1,421 hazardous waste disposal facilities believed to be subject to the U.S. Environmental Protection Agency (USEPA) monitoring requirements as of December 1984. The purpose of the national survey was to determine the adequacy of groundwater monitoring at these sites. The survey concluded that 1,246 of these facilities were subject to the groundwater monitoring requirements of the Resource Conservation and Recovery Act of 1976 (RCRA). According to the survey results, 41 percent of these RCRA facilities had nominally adequate monitoring well systems, 25 percent had inadequate groundwater monitoring systems, 17 percent had groundwater monitoring systems for which the USEPA did not know the adequacy, and 15 percent did not have any groundwater monitoring wells. These statistics indicate that the inadequacy of groundwater monitoring systems at hazardous waste facilities is a national problem.

While the national survey was in progress, the Illinois State Legislature enacted Public Act 83-1268, mandating the Department of Energy and Natural Resources to conduct a study of groundwater quality in Illinois. The results of the national survey clearly indicated, however, that an assessment of the adequacy of groundwater monitoring systems was necessary before an adequate assessment of groundwater quality could take place. The Illinois State Geological Survey (ISGS), therefore, evaluated the groundwater monitoring systems and groundwater quality in the immediate vicinity of ten hazardous waste facilities. This study resulted in the following five conclusions:

- Thorough hydrogeologic studies are necessary before an adequate monitoring program can be established. This should include greater use of such techniques as geophysics for site characterization and computer modeling to predict potential groundwater monitoring contamination resulting from site activities.
- The groundwater monitoring program of each disposal facility should be designed to fit the particular site characteristics.
- Research is needed on technical topics, such as well construction materials, well spacing, screen length, and indicator parameters.
- Careful recording of all groundwater monitoring parameters and continuing results of monitoring is paramount. The information and results from groundwater monitoring programs should be summarized periodically to allow efficient evaluation of monitoring programs and changes in site conditions.
- Records documenting monitoring programs are scarce for on-site waste disposers and generators of hazardous waste. More attention should be focussed on these types of facilities.

The project was divided into four tasks: an inventory of hazardous waste disposal sites; selection of sites for detailed study; compilation of site data; and evaluation of site data.

Task 1, the inventory of hazardous waste disposal sites, was conducted in cooperation with the first phase of another ISGS project entitled, "A Statewide Landfill Inventory," which was supported through another state entity, the Hazardous Waste Research and Information Center. Four computer databases were used to compile a list of sites known to have accepted hazardous wastes. Approximately 2,000 sites known or suspected to contain hazardous wastes were identified. Many of these sites are roadside dumps that never officially operated as waste disposal facilities; therefore, the actual types of wastes disposed of at most of the 2,000 sites are unlikely to be verified.

Task 2 involved the selection of sites for detailed evaluation of groundwater monitoring systems. Time and funding constraints limited the number of sites that could be examined in detail. It was believed that a detailed analysis of a few sites would provide more meaningful information than a cursory study of many sites. Therefore, ten hazardous waste disposal sites were selected for detailed study of their groundwater monitoring networks. These sites, which include landfills, surface impoundments, land application facilities, and a tank storage site, were chosen because they contain hazardous wastes. In addition, they have a relatively long history of groundwater monitoring, are geographically distributed throughout the state, and are believed to be of particular interest to state regulators. The sites include:

Waste Management-CID, Calumet City, Cook County
Environmental Sanitary Landfill, Joliet, Will County
SCA Services, Inc.-Wilsonville, Macoupin County
Pagel's Landfill, Rockford, Winnebago County
Peoria Disposal Company, Peoria County
U.S. Ecology, Sheffield, Bureau County
Shell Oil Company-Wood River Refinery, Roxana, Madison County
Marathon Petroleum Company-Robinson Refinery, Crawford County
Texaco Oil Company-Lawrenceville Refinery, Lawrence County
Frink's Industrial Storage, Pecatonica, Winnebago County

For task 3, compilation of site data, the ISGS evaluation team reviewed all relevant data for each site. While some information was readily accessible in ISGS files, most was obtained from files at the Illinois Environmental Protection Agency (IEPA). Site operators supplied additional information during site visits and after reviewing the draft project report.

Task 4, the evaluation of site data, is the main part of this project. In studying the ten sites, the evaluators placed emphasis on the hydrogeologic setting and the effectiveness of the monitoring network in each setting. They reviewed historical records to understand how and why the current groundwater monitoring programs developed and assessed the ability of each site's current groundwater monitoring system to detect and assess groundwater contamination. A synopsis of the detailed evaluation of the groundwater monitoring network at each site follows.

The Waste Management-CID site, located in southern Cook County, is a large (400 acres) sanitary landfill that opened in 1975 under an IEPA operating permit. Prior to Waste Management ownership, portions of the site were reportedly used for commercial liquid and solid waste disposal, uncontrolled dumping, and disposal of harbor dredging debris. Since Waste Management took over operation, sanitary refuse, sewage sludge, specially permitted hazardous and nonhazardous waste, and hazardous waste have been disposed.

While the present CID groundwater monitoring system appears adequate, two weaknesses could delay detection of contaminant migration from the site. One weakness concerns the lateral spacing of monitoring wells, which are 500 to 1200 feet apart. The well spacings are based on plume geometries predicted by a computer model designed for use with an aquifer of uniform porosity. The CID site overlies a fractured bedrock aquifer, which does not meet this criteria; therefore, the results of the model may be invalid. Secondly, the wells are located at the boundary of the CID property, making it possible for a portion of the contaminant plume, as measured by a change in specific conductance, to pass the wells before contamination would be detected in the widely spaced monitoring wells. There is no known contamination at the site.

The Environmental Sanitary Landfill (ESL), near Joliet in Will County, opened in 1972 with an IEPA permit to dispose of municipal and industrial waste, and dried sewage sludge. A portion of the site was used for land treatment of nonhazardous liquid waste; however, this practice was discontinued in 1981 when Waste Management of Illinois, Inc. purchased the site. Results of leachate analyses suggest that hazardous waste disposed of at ESL included chemical solvents, other organic compounds, and heavy metals.

The latest series of monitoring wells, installed in 1984, appears adequate in number, spacing, and chemical parameters analyzed. Two wells are not finished in the geologic unit they were intended to monitor, but they are located in non-critical areas of the site. In assessing this site, the greatest problem was lack of historical data. Although groundwater contamination is suspected at ESL, the source is difficult to determine without historical data.

The SCA Services, Inc.-Wilsonville site is an industrial waste landfill located on 130 acres (11 acres contained trenches) in southeastern Macoupin County. It opened in 1976 and accepted more than 85,000 barrels of waste before closing in 1981. Disposed waste came from the following industries: chemical, iron/steel foundry, photofinishing, fertilizer, plating/polishing, utilities, paper/printing, and military/ammunition. The site was ordered closed and exhumed by 1987, the result of a lawsuit by Wilsonville residents against the site owner. Approximately coincident with the court order, groundwater contamination was discovered at the site.

The monitoring scheme at the Wilsonville site has always been above minimum statute requirements, and remains adequate for detection monitoring. The extent of the groundwater contamination, however, has never been adequately defined. To do so will require a more extensive groundwater monitoring network.

Pagel's Landfill is a 60-acre waste disposal site that opened in 1972 in southeastern Winnebago County. The site accepted municipal refuse, sewage sludge, inorganic compounds, heavy metals, and minor amounts of organic liquids. This landfill was constructed with an asphalt liner and a leachate collection system. Significant groundwater contamination in the form of organic priority pollutants has been observed in monitoring wells around the site. Because Pagel's Landfill is adjacent to the Acme Solvents site, which also disposed of hazardous wastes, precise determination of the contamination source is difficult.

The groundwater monitoring system at Pagel's Landfill was inadequate until 1981, when groundwater contamination occurred near the site. Since then, the groundwater monitoring system has been greatly improved, but it is still not possible to identify exactly the contamination source because of mixing of contaminants from the two adjacent waste disposal sites. A second problem is that the site overlies fractured dolomite, which is extremely difficult to monitor adequately.

The Peoria Disposal Company, Inc. has operated a landfill just west of Peoria in Peoria County since 1968. A land-application area, formerly used for liquid waste, is no longer operated. The site currently accepts special and hazardous wastes, most of which are iron/steel foundry wastes considered hazardous because of high concentrations of heavy metals. Although variations in groundwater quality can be mapped at the site, no contamination has reportedly been detected at the Peoria Disposal Company site.

The original groundwater monitoring system was inadequate and poorly documented. Significant improvement has occurred, especially in the last few years, so that the number and placement of wells now appear sufficient for monitoring the active landfill areas. The parameters analyzed also appear adequate.

The U. S. Ecology No. 2 landfill in southwestern Bureau County accepted a large variety of chemical wastes beginning in 1974. Wastes have not been accepted since 1983 and official closure is pending. Contamination is evident at the site.

Prior to 1980, the groundwater monitoring system at the U. S. Ecology No. 2 was inadequate in the number of wells and parameters monitored. Since then, numerous wells have been added and the list of monitored parameters has been upgraded. The main problem with the current groundwater monitoring network is that some of the wells have no annular seals, while others monitor more than one permeable zone. These practices can lead to contamination of clean zones. The problem wells will be plugged or reconstructed as part of the site closure.

The Shell Oil Company-Wood River manufacturing complex, located in Madison County on the east bank of the Mississippi River, has operated a refinery since 1917. Waste disposed in a 15-acre, unlined surface impoundment comes from the effluent treatment unit and the process sewer system. These wastes are considered hazardous due to the possible content of chromium and lead. Groundwater contamination is suspected at the facility.

The facility currently has wells for both detection and assessment monitoring. The assessment monitoring system appears adequate, but the detection wells are not in all the most probable contaminant pathways and samples from them have not been analyzed for all the inorganic contamination parameters.

The Marathon Oil Company-Robinson Refinery, located in eastern Crawford County, operates three surface impoundments and a land treatment facility. The impoundments are used only for waste storage, while the land treatment facility is used for disposal. Among the wastes disposed of on-site are dissolved air flotation (DAF) skimmings, "slop" oil emulsions, and various sludges--all considered hazardous. Groundwater contamination has not been detected by monitoring wells at the site.

Based on information available to the ISGS, the groundwater monitoring system appears inadequate. Some wells are too distant from waste disposal areas to provide early detection of contamination. In other cases, Marathon is monitoring wells that are not finished in the most permeable geologic unit. Marathon also does not test wells specifically for lead and chromium, components that cause waste to be classified hazardous.

The Texaco Oil Company-Lawrenceville refinery operated a landfarm and a surface impoundment in southeast Lawrence County until it closed in 1985. Wastes from petroleum refinery processes, which are hazardous due to lead, chromium, and corrosiveness, were disposed of on-site. Groundwater contamination is suspected.

The groundwater monitoring system at Texaco appears marginally adequate; however, the available information on the groundwater monitoring system was insufficient to allow a thorough examination. For example, unmonitored permeable zones may exist at the site. Available records indicate that appropriate indicator parameters are being analyzed. The only problem readily apparent from the records is that some of the wells are too far from the disposal areas to allow an early indication of contaminant migration.

Frink's Industrial Waste storage facility began operation in 1975 in western Rockford County. Waste oils, metal-bearing liquids, and chemical solvents were stored in 17 tanks and two lagoons. Groundwater contamination is confirmed at the site, and no wastes have been received since September 1985. Thirteen of the tanks have been cleaned or removed.

The groundwater monitoring system at Frink's is inadequate. Monitoring of groundwater in the bedrock is insufficient and necessary information on direction of the groundwater flow is missing. Although incomplete, data on well construction indicate that wells were improperly constructed and may be a pathway for contaminant transport.

The ten sites studied demonstrate that groundwater monitoring programs at hazardous waste disposal facilities have improved significantly in the past ten years. Since RCRA was enacted in 1976, information from the successes and failures of hazardous waste disposal activities has aided the improvement of subsequent groundwater monitoring programs. Much of the improvement in Illinois, however, can be attributed to the IEPA, which has more stringent requirements than RCRA.

Prior to the creation of the IEPA in 1971, little attention appears to have been extended to groundwater monitoring at hazardous waste sites. For the few sites that had groundwater monitoring programs, information about these programs such as records of borings, well construction, and analytical procedures was sparse or nonexistent. After IEPA came into existence, sites were required by permit to have groundwater monitoring programs.

The early (pre-RCRA) permits generally required only limited groundwater monitoring. Groundwater monitoring technology was in its infancy and research on groundwater contaminant transport was sparse, compared with its current level. Permits specified as few as two to as many as 14 monitoring wells. The number of wells required appears to have coincided with the number of wells proposed by the operator. Wells were typically constructed of PVC (polyvinyl chloride) plastic casing with solvent-cemented couplings, the least expensive materials available. They were to be monitored quarterly for as few as three parameters. Permits seldom specified depths and well locations. Records of construction details for many of the first monitoring wells no longer exist. Nine of the ten groundwater monitoring programs studied were originally inadequate for detection monitoring.

Groundwater monitoring programs greatly expanded after RCRA was implemented. RCRA required a minimum of four monitoring wells--one upgradient and three downgradient. Most hazardous waste sites operating in Illinois already meet the minimum requirement. Owners of many newer sites proposed, and regulatory officials accepted, groundwater monitoring plans that situated the four wells at the corners of the waste disposal site. However, the RCRA provided a mechanism for the IEPA to require more extensive monitoring programs.

Even as this study took place, groundwater monitoring programs were changing at many of the selected sites. Some sites, which had inadequate groundwater monitoring programs when this study began in 1984, now have sufficient programs. Many sites are currently in transition due to recent closure, remedial actions, or application for a RCRA part B permit. By 1986, six of the ten sites had at least marginally adequate groundwater monitoring systems, while the other four had far fewer deficiencies than their original systems. Because of these recent activities, the groundwater plans of these facilities are likely to continue to improve. We see this trend toward more complete and sophisticated groundwater monitoring programs as positive and believe this evolution will continue. The recommendations outlined at the beginning of the summary, however, would enhance the monitoring programs at all hazardous waste facilities.

INTRODUCTION

Illinois is a state with significant groundwater resources. In 1986, groundwater in Illinois was withdrawn at a rate of about 960 million gallons per day (table 1). In many rural areas, groundwater is the only source of water available for domestic, livestock, municipal, industrial, and irrigation use. Clean groundwater is vital to Illinois for human consumption, industry, and agriculture. The land disposal of hazardous wastes, however, can threaten the quality of the state's groundwater supplies.

The U. S. Office of Technology Assessment (OTA, 1983) estimates that 5 to 10 percent of all disposal sites in the United States will eventually require remedial clean-up of toxic substances which have been released to the environment. Sites without an identified responsible party will appear on the Superfund National Priority List. OTA also estimates that the 526 sites from the Superfund National Priority List which have had observed releases of toxic substances into the groundwater may potentially contaminate the water supplies used by eight million Americans. At 350 of these 526 sites, groundwater is the only local source of drinking water available to the population at risk (OTA, 1983). Groundwater monitoring programs are designed to detect contamination originating at waste disposal sites. If detected in time, remedial actions may be initiated before significant contamination of the groundwater resource occurs.

The Currie Bill (Illinois Public Act 83-1268) mandated the Department of Energy and Natural Resources (ENR), in cooperation with the Illinois Environmental Protection Agency and the Illinois Department of Public Health, to conduct a study of groundwater quality in Illinois. The study was to give priority to the assessment of groundwater quality near hazardous waste facilities and include recommendations for implementing an effective state groundwater protection program.

The need for such a study is evident in the results of the recent Groundwater Monitoring Survey conducted by the U.S. House of Representatives in 1985. A questionnaire was sent to 1,421 hazardous waste disposal facilities believed to be subject to USEPA monitoring requirements as of December 1984. The national survey determined that 1,246 of these facilities were subject to groundwater monitoring requirements of the Resource Conservation and Recovery Act of 1976 (RCRA). Of these RCRA facilities, 41 percent had nominally adequate monitoring well systems, 25 percent had inadequate groundwater monitoring systems, 17 percent had groundwater monitoring systems for which the USEPA does not know the adequacy, and 15 percent reportedly had no groundwater monitoring wells. These statistics indicate that the groundwater quality at more than half of the hazardous waste facilities in the United States cannot be determined with current groundwater monitoring systems. Thus, the question of the impact of hazardous wastes on groundwater quality in Illinois becomes the challenge of whether groundwater quality in Illinois can be accurately assessed in the vicinity of hazardous waste facilities. Once the answer to the

Table 1 Summary of total water withdrawals, 1986 (from Kirk, 1987)

Category	*Groundwater*	*Surface water*	*Total*
Public system	437.1	1369.0	1806.1
Self-supplied industry	204.2	35,331.3	35,535.5
Rural (domestic, livestock and irrigation)	305.9	*	305.9
Fish and wildlife	11.6	25.1	36.7
Total	958.8	36,725.4	37,684.2

* All rural use is considered to be groundwater, although no attempt was made to separate sources in Kirk's study. Measurement is in million gallons per day (mgd). Figures may not add up to totals shown because of independent rounding.

second question is affirmative, the first question can be addressed. This report addresses the second question by evaluating the groundwater monitoring systems at ten hazardous waste facilities in Illinois.

In this study, the State Geological Survey evaluated the groundwater quality and monitoring systems in the immediate vicinity of ten hazardous waste facilities. The draft report was completed in August 1985 and sent to various state agencies and the ten sites evaluated in the study. In response to the draft, several site representatives sent additional information, some of which reflected major changes in the site's groundwater monitoring programs since the study began. This final version includes new information and comments received through February 1986.

Groundwater Monitoring Regulations

Disposal of hazardous wastes is regulated at the federal level under the Resource Conservation and Recovery Act of 1976 (RCRA). Federal jurisdiction of hazardous waste disposal was deemed necessary to prevent states with lax regulations from becoming dumping grounds for other states' wastes and to force industry to abide by regulations designed to protect human health and the environment. RCRA does provide states with the option of implementing their own programs which must be at least as stringent as the federal program. Illinois, like many other states, has applied for primacy in regulating hazardous waste disposal.

Requirements for monitoring groundwater at hazardous waste management facilities in Illinois are contained in Subpart F, Section 725, of Rules and Regulations of the State Title 35 of Illinois (Environmental Protection), Subtitle G (Waste Disposal), Chapter I (Pollution Control Board). The regulations are similar to those defined by RCRA and administered by USEPA. The requirements apply to all facilities in existence on November 19, 1981. By that date, harzardous waste management facilities, including surface impoundments, landfills, land treatment or tank facilities, were required to implement a groundwater monitoring program capable of determining the facility's impact on the quality of groundwater underlying the facility. The plan for the monitoring system requires the approval of the IEPA. For hazardous waste disposal facilities, most monitoring plans are carried out during the active life and post-closure care period of the facility.

According to the IEPA rules, a groundwater monitoring system must be capable of yielding groundwater samples for analysis and must include monitoring wells installed both hydraulically upgradient and downgradient from the waste management area. The regulations require the installation of at least one upgradient monitoring well, which is a minimal requirement. Because of the spatial variability of the groundwater flow system in the vicinity of a site, most facilities require more than one upgradient well. The number, locations and depths of these upgradient wells must be sufficient to yield groundwater samples that are representative of groundwater quality near the facility, but not affected by it.

Monitoring wells must also be installed downgradient of the waste management areas. These wells must be situated within 10 to 25 feet of the property lines or waste boundary. While a minimum of three downgradient wells is required, most facilities require significantly more wells to enable immediate detection of hazardous waste migration or hazardous waste constituents from the waste management area. The agency also may require the installation of additional monitoring devices, such as piezometers and lysimeters.

The regulations require all monitoring wells to be constructed in a manner that "maintains the integrity of the monitoring well borehole." This is stipulated to prevent leakage of water and contaminants in the annulus of the borehole outside the well casing. The annular space above the sampling depth must be sealed with a "suitable material", such as cement grout or bentonitic clay slurry, to prevent contamination of samples and groundwater.

Inventory of Hazardous Waste Disposal Sites

The first step in evaluating groundwater monitoring systems at hazardous waste sites was to inventory the waste disposal sites, emphasizing those sites which accepted hazardous wastes. The inventory, gathered from various computer databases, was then used to select sites for detailed evaluation.

The data source for the project was eight magnetic-tape data files maintained by the Illinois Environmental Protection Agency (IEPA), two magnetic-tape files compiled by the United States Environmental Protection Agency (USEPA) and available through the National Technical Information Service, and an ISGS project, "Statewide Landfill Inventory" (Dixon et al., 1986). One IEPA file, both USEPA files, and the Statewide Landfill Inventory contained data which facilitated the inventory. Information contained in the IEPA and USEPA files included site name, location, size, methods of disposal, type of waste handled, known or suspected releases of contaminants to the environment (if any), owner, operator, and other miscellaneous data. The Statewide Landfill Inventory assisted in identifying potential landfill sites for inclusion in the study.

Data on the tapes were written in code. A computer program was written to interpret the codes and sort out the disposal facilities identified as having accepted hazardous wastes. The sorting process identified approximately 2,000 sites listed by IEPA which may have accepted hazardous waste. Included among these 2,000 sites were numerous small roadside dump sites which never officially operated as landfills. Information on materials disposed of at these small facilities is not easily obtained and may not exist for many sites. Therefore, it is unlikely that the waste types at all of these 2,000 sites will ever be known.

Site Selection

A large number of disposal sites in Illinois have accepted hazardous wastes. Monitoring programs vary from site to site and, through time, at individual sites depending on regulations current when the monitoring program was established, local hydrogeologic conditions, and site operations. Since it was impossible to conduct detailed studies of all of these sites and their associated monitoring programs in the time allowed, ten representative sites were selected for detailed evaluation.

Table 2 lists the ten sites selected for detailed study, their locations, and whether there has been any documented release of contaminants. Figure 1 shows the location of each site. The landfill sites and the tank storage site were chosen because they may have accepted hazardous wastes, have groundwater monitoring programs, and are believed to be of particular interest to state regulators. The surface impoundment and land application sites were chosen because they were the only known monitored sites in each category, as listed on the IEPA Selected Inventory file, to accept hazardous wastes for disposal. In actual practice, the U.S. Ecology and Frink's Industrial waste sites once operated surface impoundment facilities and the Peoria Disposal and Environmental Sanitary Landfill sites formerly practiced land spreading for the disposal of hazardous wastes.

Compilation of Site Data

The ISGS team reviewed all available data for each selected site. Some data were available at the ISGS, while a large amount of data were in IEPA files. A request was made to the IEPA Freedom of Information Act officer, at the suggestion of the IEPA, to obtain access to and copying priveleges of relevant files. The ISGS team made several visits to the IEPA and collected several thousand pages of documents. Site operators also provided data during visits to the sites and following their review of the draft report. The team visited five of the ten sites for the project; one site has closed and could not be visited; two sites (Marathon and Frink's Industrial Waste) denied access to ISGS scientists; and two sites (Wilsonville and U.S. Ecology) had been visited by ISGS personnel on several previous occasions.

Figure 1 Locations of sites selected for detailed study.

Table 2 Sites chosen for detailed study

Site Name	*Location*	*Contaminant Release**
Landfills		
Waste Management-CID	Calumet City	none
Environmental Sanitary Landfill	Joliet	suspected
SCA Services, Inc.-Wilsonville (previously Earthline)	Wilsonville	known
Pagel's Landfill	Rockford	suspected
Peoria Disposal Company	Peoria	none
U.S. Ecology	Sheffield	known
Impoundments		
Shell Oil Company-Wood River Refinery	Roxana	suspected
Land Application		
Marathon Petroleum Company-Robinson Refinery	Robinson	none
Texaco Oil Company-Lawrenceville Refinery	Lawrenceville	suspected
Tank Storage		
Frink's Industrial Waste	Pecatonica	known

*Release of contaminant information is as listed in computer databases. Actual conditions may vary.

Evaluation of Site Data

To assure quality control, uniform criteria in assessing groundwater monitoring programs were used to evaluate all sites. This permitted better organization and greater utility of the data, and pointed to inadequacies in the database. Factors considered included hydrogeologic conditions, number and distribution of monitoring wells, intervals and geologic materials monitored, well construction materials and techniques, chemical parameters used for analyses, and changes in water quality with time and space.

One factor of concern was temporal changes in water quality in individual wells, which could indicate contamination. Time-series analyses of trends in water quality indicator parameters were developed for monitoring wells at seven sites, using the IEPA Water Quality Analysis master file. This proved to be a lengthy and difficult process, requiring extensive computer processing. Unfortunately, the database contained little water quality information and covered short time periods for most sites, so few conclusions could be drawn. In addition, computer files were not available for the Wilsonville, Marathon, or Shell sites. Although most of the time-series analyses were inconclusive, spatial distributions of chemical parameters could be mapped for many sites.

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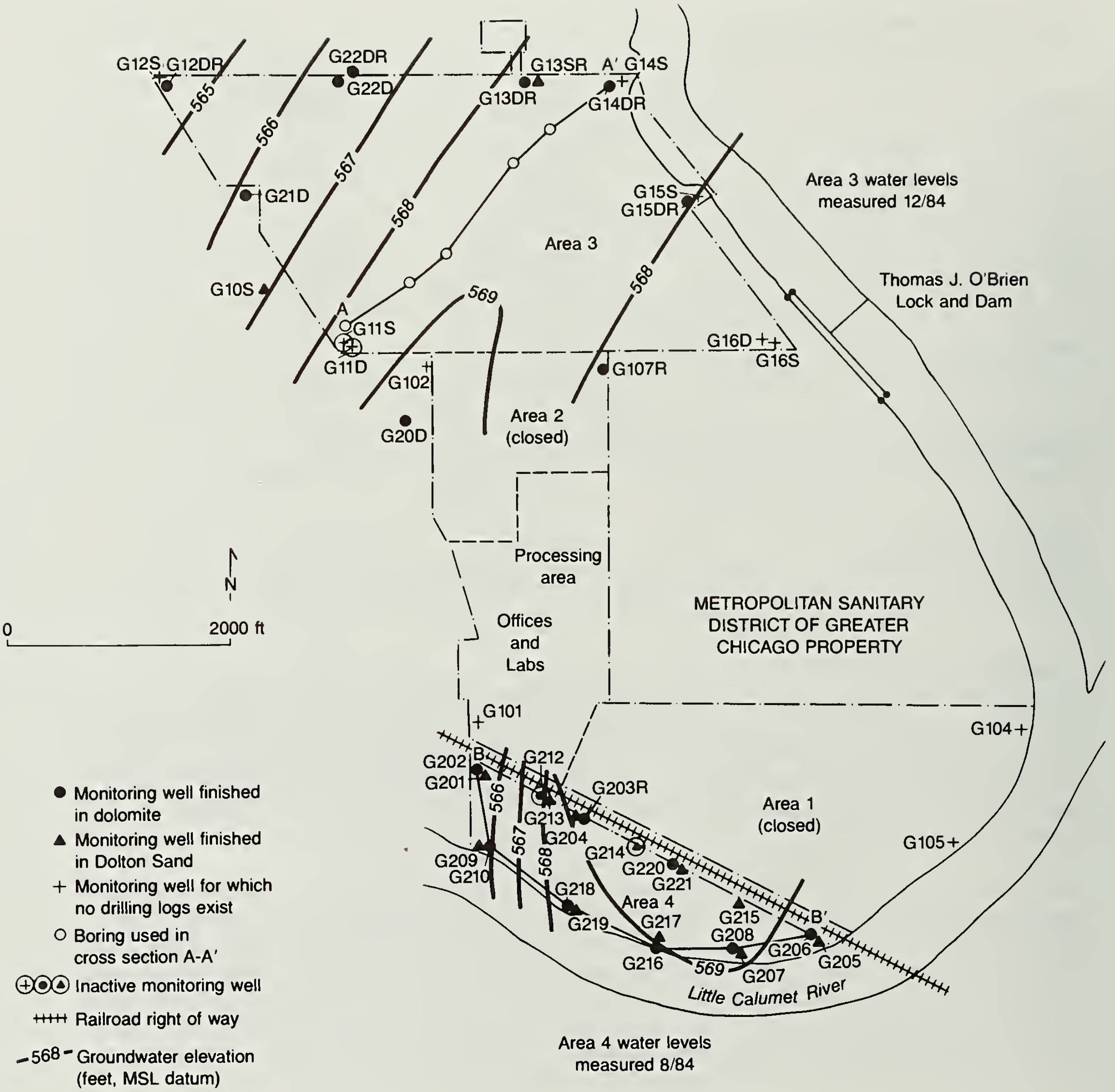

Figure 2 Map of Waste Management CID landfill showing disposal areas, well locations, potentiometric surface of the mapped dolomite aquifer, and lines of cross section.

Site Description

The Waste Management of Illinois, Inc.-CID site, located in southern Cook County, opened in 1975 under an operating permit from the Illinois Environmental Protection Agency (IEPA). This site lies within portions of N 1/2 Section 1, T36N, R14E; W 1/2 and W 1/2 of SE 1/4 Section 36, T37N, R14E; NE 1/4 Section 35, T37N, R14E. Prior to ownership by Waste Management of Illinois, Inc. (WMI), portions of this site were used for disposal of commercial liquid and solid waste, uncontrolled dumping, and contaminated harbor-dredging debris (Woodward-Clyde Consultants, 1983; Technos, 1984; Colton, 1985). WMI has operated four disposal areas (combined size, approximately 400 acres). Areas 1 and 2 (fig. 2) opened in 1975 and accepted sanitary refuse, sewage sludge, and special nonhazardous permitted waste. These areas are now closed. Area 3, also known as CID II, opened in 1979 and accepted sanitary refuse, specially permitted hazardous and nonhazardous waste, and hazardous waste until January 1983. The wastes included sewage sludge, electroplating wastes, incineration ash, and other nonliquid materials. Area 3 now accepts only sanitary and specially permitted nonhazardous waste. Area 4, opened in January l983, presently accepts special and hazardous waste similar to that previously accepted at Area 3. Leachate collection systems are in operation at Areas 3 and 4.

ISGS personnel visited the CID site in May 1985. At the time of the visit, landfilling operations were active in Area 3 (sanitary refuse) and Area 4 (hazardous waste). Site personnel reported that new monitoring wells were being installed at the time.

Geology and Hydrology

The CID site is situated on the former lake bed of glacial Lake Chicago. The Little Calumet River, adjacent to site Areas 3 and 4, carries local surface drainage southwest toward the Illinois River and the Mississippi River drainage system. Flow in the Little Calumet River is controlled at the Thomas J. O'Brien lock and dam and reportedly poses very little threat of flooding at the CID site (WMI, 1978).

Cross sections A-A' (fig. 3) and B-B' (fig. 4) show the stratigraphy of the glacial deposits at Areas 3 and 4, respectively.

The surficial material through much of the CID site is fill from waste disposal activities prior to current site operations. This fill material may exceed 25 feet in thickness at some areas.

The uppermost geologic unit present at the site is the Dolton Member of the Equality Formation. This silty sand was most probably deposited in a lacustrine environment, as a beach, bar, or spit deposit typical of near-shore, shallow water environments (Woodward-Clyde Consultants, 1984). The maximum thickness of the Dolton Sand locally is 12 feet; however, the sand is absent in places where it was excavated for construction fill. WMI removed the sand and the fill above it during excavation of the Area 3 and 4 disposal cells.

The Dolton Sand is a water-bearing unit; however, no wells are known to pump water from this unit (Woodward-Clyde Consultants, 1984). The hydraulic conductivity of the sand, calculated from field bailer tests, reportedly ranges from 10^{-3} to 10^{-5} cm/s (Woodward-Clyde Consultants, 1984). This range of hydraulic conductivity is typical for a silty sand. Groundwater from the Dolton Sand discharges to the Little Calumet River (Woodward-Clyde Consultants, 1984).

Beneath the Dolton Sand lies the Wadsworth Member of the Wedron Formation. Woodward-Clyde Consultants (1983) locally describes this member as having three units consisting of glacially deposited tills. The basal unit, a very hard, overconsolidated, pebbly silty clay with occasional cobble and silty zones, lies directly on the dolomite bedrock. This type of hard till is often referred

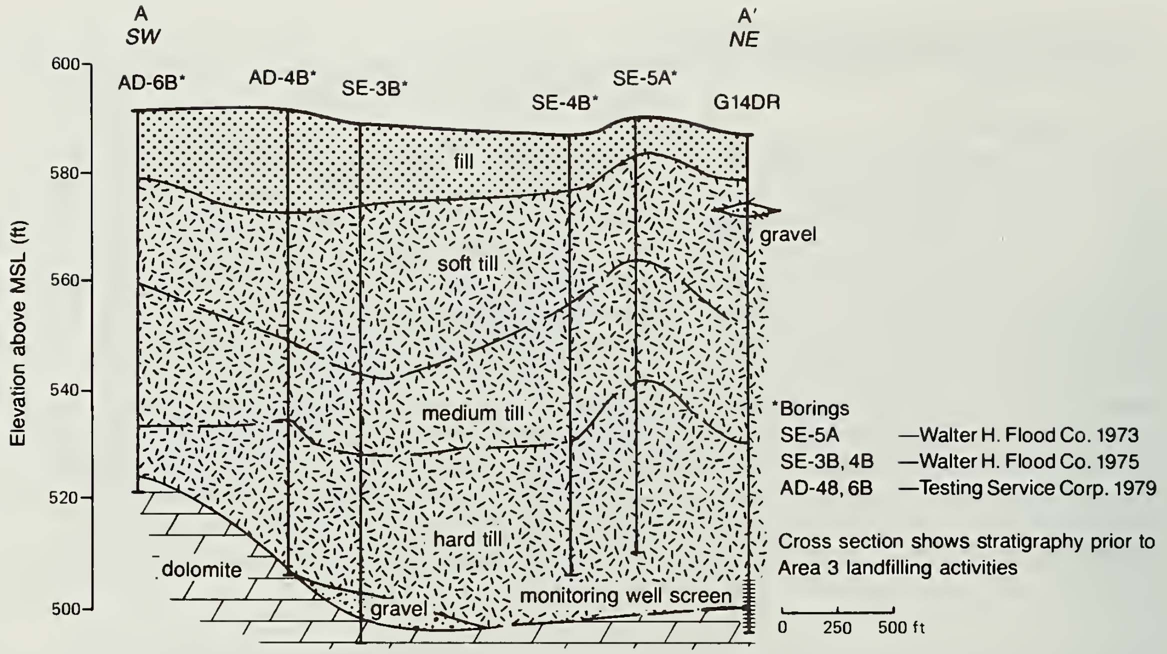

Figure 3 Waste Management CID cross-section A-A', southwest-northeast through center of waste disposal Area 3.

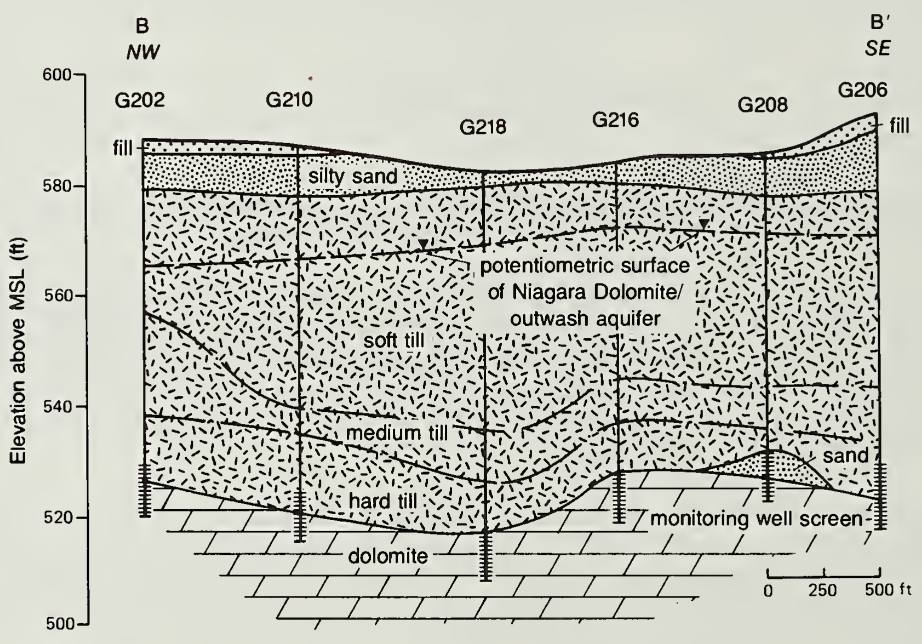

Figure 4 Waste Management CID cross-section B-B', northwest-southeast along south boundary of waste disposal Area 4.

to as hardpan. The overlying two units are progressively softer, pebbly, silty clays. The combined thickness of the Wadsworth is 40 to 90 feet. However, the average thickness through most of the site, excluding the cell areas, is 60 to 80 feet. Because the cells were typically excavated to depths of 20 to 40 feet, the thickness of till under the cells is less. The laboratory tests results of hydraulic conductivity, conducted on undisturbed samples from all three units, range from 10^{-7} to 10^{-8} (cm/s) (Woodward-Clyde Consultants, 1983). Trench excavations have reportedly shown no signs of fractures in the clay, which, if present, would allow water to move through the till faster than suggested by the measured hydraulic conductivity values (Woodward-Clyde Consultants, 1983). The Wadsworth Till reportedly functions as an aquitard between the Dolton Sand and the underlying Niagara Dolomite (Woodward-Clyde Consultants, 1983).

The Silurian-age Niagara Dolomite, 45 to 90 feet below ground surface, is locally about 440 feet thick (Woodward-Clyde Consultants, 1983). The unit has at least two zones of moderate hydraulic conductivity, separated by a layer of dense, low permeability rock (Canonie, 1985a). The upper moderate conductivity zone is recognized as the uppermost aquifer for groundwater monitoring purposes in the CID area. Contained in the weathered surface of the dolomite bedrock, the upper zone is 5 to 20 feet thick. Hydraulic conductivities in this zone range from 10^{-4} to 10^{-6} cm/s (Canonie 1985a). Field measured hydraulic conductivities in the dolomite immediately below the weathered zone range from 10^{-6} to 10^{-7} cm/s (Canonie, 1985a). The depth to the next permeable zone is estimated to be nearly 200 feet (Canonie, 1985a).

Regional groundwater flow, based on deep wells in the Niagara Dolomite, is toward the southeast. Water level measurements in the CID monitoring wells (open to the weathered zone in the dolomite), however, indicate flow toward the southeast and the west (fig. 2). The flow's westward diversion in the weathered zone is reportedly due to seepage of water into several Metropolitan Sanitary District of Greater Chicago (MSDGC) dropshafts (Canonie 1985a), located 1 to 3 miles west of the site.

In addition to the MSDGC dropshafts, at least six water wells within a 1-mile radius of the CID site are finished in the dolomite aquifer at depths of 200 to 450 feet. The Silurian Dolomite is separated from the underlying high water-yielding Cambrian-Ordovician aquifer by approximately 100 feet of low permeability Maquoketa Shale.

Groundwater Monitoring History

When Areas 1 and 2 opened in 1975, five monitoring wells, G101-G105 (fig. 2), and eight piezometers (not shown in fig. 2) were installed to collect groundwater samples and measure groundwater levels, respectively. None of the wells penetrated the dolomite. At least one of the wells was probably finished in the surficial fill material. The material in which the other wells are finished is uncertain (WMI personnel state that the wells are open to both till and sand). The monitoring wells were located at corners of the site without consideration of groundwater flow directions. Well G103 was replaced with well G107 in 1979; well G107 was subsequently added to the original Area 3 monitoring program. Based on available data, the depths and locations of the eight piezometers cannot be positively ascertained. The original, 1975 operating permit stated that Area 1 and 2 monitoring wells should be sampled quarterly for total dissolved solids (TDS), chloride (Cl), iron (Fe), total chromium (Cr), cyanide (CN), lead (Pb), mercury (Hg), sulfate (SO4), chemical oxygen demand (COD), and water level.

WMI installed 13 additional monitoring wells (G107, G11S-16S, and G11D-16D) when Area 3 was opened in 1979. The S series wells were intended to be used as Dolton Sand monitoring wells. There are no known boring logs or well completion reports for these wells; however, WMI personnel state that the wells are finished in the sand. The D series wells and well G107 were intended for use as monitoring wells in the weathered dolomite aquifer; however, no boring logs or well completion reports exist for these wells. Two separate investigations of the D series wells in 1982 and 1985 concluded that wells G107, G11D-15D were finished in the hard basal till rather than in the dolomite (Woodward-Clyde Consultants, 1983; Canonie, 1985b). These wells sub-

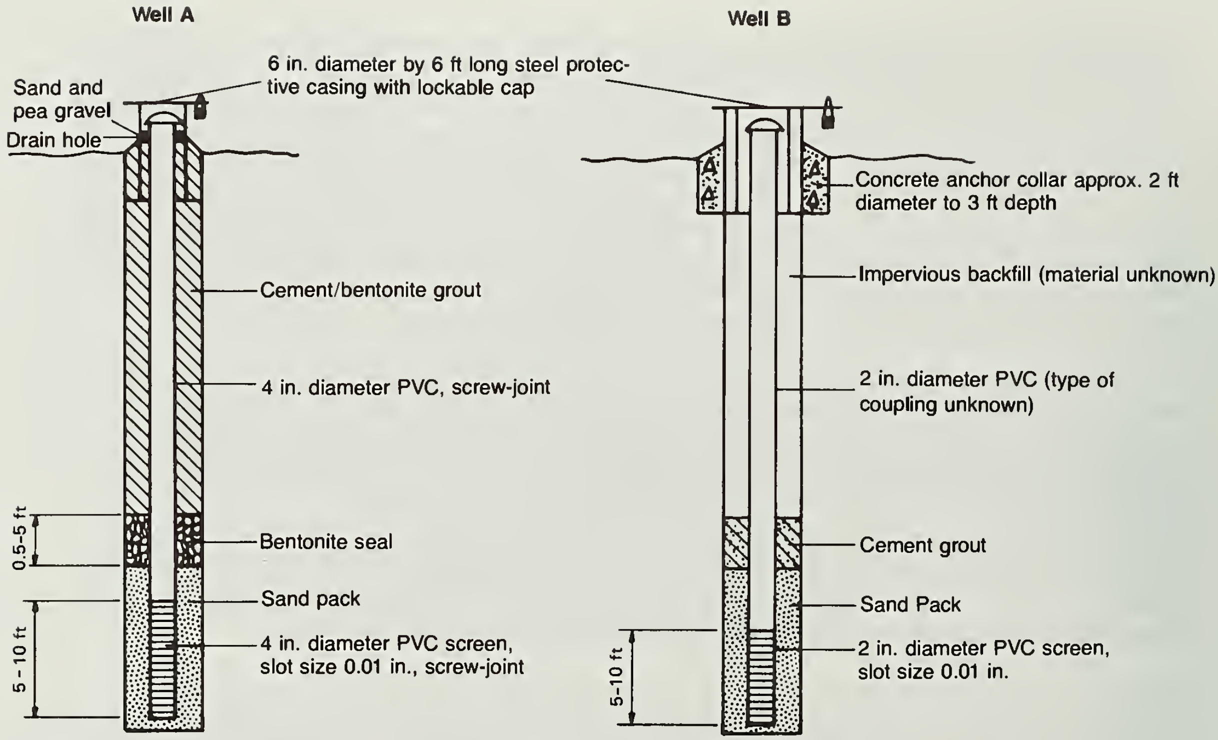

Figure 5 Typical construction of monitoring wells at Waste Management CID landfill. Well A represents wells completed after 1982; Well B typifies wells constructed prior to 1982.

sequently were replaced with wells G107R, G12DR-15DR, and G20D (to replace G11D). WMI istalled two more wells, G21D and G22D, in 1984 and 1985 to monitor groundwater flow west toward the MSDGC dropshaft. WMI also installed wells G10S and G13SR in 1985 to monitor groundwater flow in the Dolton Sand.

Area 3 now has 15 wells to monitor groundwater flow. Nine wells are in the dolomite--four to monitor groundwater flowing toward the southeast, four to monitor groundwater flowing toward the west, and one (G20D) to monitor groundwater quality upgradient of the disposal area. The wells are spaced at 700 to 1200 feet intervals. Six other wells monitor groundwater in the till and/or in the Dolton Sand (fig. 2).

Area 4 has been used for disposal of processed, solid, hazardous wastes since January 1983. WMI drilled 10 borings during the initial site evaluation (1982) to determine the hydrogeology at the site. Monitoring wells G201-210 were completed in these borings (fig. 2). The initial monitoring system in Area 4, therefore, consisted of five wells finished in dolomite and five shallow monitoring wells finished in the Dolton Sand. The wells were installed in the northwest and southeast portions of Area 4, which left a large gap in the monitoring well coverage in the southwest (downgradient) portion of Area 4 along the Little Calumet River, and along the northeast (upgradient) boundary (fig. 2).

In 1983 and early 1984, five new wells (G213, G215, G217, G219, G221) in Area 4 were finished in the Dolton Sand, three new wells (G216, G218, G220) were finished in the Niagara Dolomite, and G203R replaced one of the original Area 4 monitoring wells. The new wells fill the gaps in the northeast and southwest parts of the area. Currently, Area 4 has seven downgradient wells to monitor groundwater flow in the dolomite and two upgradient wells (G203R and G220). The

downgradient wells are all spaced at 500 to 800 feet intervals. Ten wells, spaced less than 1000 feet apart, monitor groundwater in the Dolton Sand.

The monitoring wells installed at CID prior to 1982 have neither boring logs nor construction records. Many of these wells have been replaced because they had not been installed in the dolomite. Figure 5 shows the typical construction of these wells. Records of the early wells, constructed of PVC pipe and screen, do not include information on the presence of PVC solvent cement, which contaminates water samples with organic compounds. Screen lengths were reportedly 5 to 10 feet. All new and replacement wells installed since 1982 have been constructed with 4-inch ID (inside diameter) screw-jointed PVC. Screen lengths are approximately 5 feet for till and sand wells and 10 feet for dolomite wells.

Monitoring at CID is currently under the jurisdiction of two regulatory programs, the Resource Conservation and Recovery Act (RCRA) and IEPA permit. Table 3 gives the designation of the regulatory program for each monitoring well; table 4 lists the parameters selected for analysis for the monitoring wells in Areas 3 and 4.

The IEPA Water Quality Analysis Master provided the chemical composition of samples from the CID monitoring wells. Five indicator parameters--specific conductance (SC), total organic carbon (TOC), chloride (Cl), residue on evaporation (ROE), and total organic halogen (TOX)--were compared for shallow and deep wells in Areas 3 and 4, as well as for wells in Areas 1 and 2 (table 5). Based on this comparison, several conclusions can be made about groundwater quality at the CID site.

Water samples taken from the shallow monitoring wells (finished in the Dolton Sand) generally have lower quality than those from the dolomite aquifer (table 5 and fig.6). In particular, wells G11S (which has since been decommissioned) and G16S (Area 3), and G204, G209, G213, and G221 (Area 4) have much lower quality water than that of both the deep and the other shallow wells. However, not enough historical data from these wells exist to determine trends through time. Therefore, no conclusion can be made on whether the source of these high indicator values is recent land-filling activities or uncontrolled dumping activities prior to the establishment of the CID site.

There is no evidence of contamination in the dolomite aquifer resulting from activities at CID. This conclusion is based on the review of the limited available data from the monitoring wells finished in this aquifer prior to July 1985, and on data reported in a geophysical study of the site (Technos, 1984).

Evaluation of Groundwater Monitoring Program

The Waste Management, Inc.-CID facility has two disposal areas which have accepted hazardous waste. These two areas presently appear to be in compliance with IEPA and RCRA standards concerning the number and design of monitoring wells finished in the shallowest underground source of drinking water, the Niagara Dolomite, which is designated to be the uppermost aquifer for monitoring purposes.

WMI has upgraded its monitoring systems in both hazardous waste disposal areas. Due to insufficient records and suspected faulty well construction, many of the original Area 3 wells were replaced. They were either pulled or over drilled. The open holes were then backfilled with a Portland cement and bentonite grout (Canonie, 1985b). Additional wells were added in both disposal areas after the discovery that groundwater flow was being diverted to the west by the MSDGC dropshafts.

While the present CID groundwater monitoring system appears adequate, one potential weakness, well spacing, could possibly result in delayed detection of contaminant migration from the

Table 3 CID monitoring wells under jurisdiction of RCRA and IEPA regulations

RCRA wells	Area 3	G12DR, G13DR, G14DR, G15DR, G20D, G21D, G22DR, G107R
	Area 4	G202, G203R, G206, G208 G210, G216, G218, G220
IEPA wells	Area 3	G10S, G12S, G13SR, G14S, G15S, G16S, G12DR G13DR, G14DR, G15DR, G16D, G20D, G107R
	Area 4	G201, G204, G205, G207, G209
	Areas 1 and 2	G213, G215, G217, G219, G221 G101, G102, G104, G105

Table 4 Water quality parameters analyzed in samples from CID monitoring wells (WMI,1985)

1. ***RCRA monitoring:*** The Niagara Dolomite Aquifer is considered the shallowest underground source of drinking water at CID; thus, it is the only aquifer which must be monitored under RCRA. All Area 3 and 4 wells finished in the dolomite are monitored for:

Semiannually	***Annually***	
pH	Na	Fe
Specific conductance	Cl	Mn
TOC (total organic carbon)	SO_4	Phenols
TOX (total organic halogen)		

2. ***EPA permit, Area 3:*** The State of Illinois requires wells finished in the dolomite and in the sand or till at Area 3 to be sampled quarterly for:

Xylene*	pH	B
Methylene chloride	Fe	Ni*
CN (Cyanide)*	TOX	Zn*
NH_3 (Ammonia)	TOC	Cr
1,1,1-Trichloroethane	COD	Toluene
ROE (residue on evaporation)		
Elevation of groundwater surface		

3. ***IEPA permit, Area 4:*** The wells finished in the Dolton Sand at Area 4 are required to be sampled quarterly for:

Xylene	Fe	Mn
Methylene chloride	pH	TOC
Specific conductance	Toluene	TOX
1,1,1-Trichloroethane	Alkalinity	ROE
Water temperature	B	Phenols
Elevation of groundwater surface	Cl	Na
		SO_4

*Parameter tested for in samples only from sand or till wells

Table 5 Analytical measurements of five indicator parameters for contamination of water samples taken from CID monitoring wells.

		Well series				
		Area 3		Areas1 and 2	Area 4	
Parameter		*Shallow**	*Deep*		*Shallow*	*Deep*
SC	Range	690-11,550	411-595	514-1280[(1)]	1355-14,560	413-910[(2)]
μmhos/cm	Average	3500 (2200)	520	897	5400	500
TOC	Range	11-840	2-65	3-45	3-345	no data
mg/L	Average	95 (26)	4.2	10	63	
Cl	Range	17-400	29-110	22-200	40-5680	29-100[(2)]
mg/L	Average	(120)	45	80	1284	44
ROE	Range	510-8000	250-720	290-1067	900-11,700	no data
mg/L	Average	3300 (2100)	355	555	4134	
TOX	Range	5-2620	5-55	5-68	12-690	no data
μg/L	Average	470 (37)	22	8	130	

Ranges are taken from results of all sampling events between July 1980 and July 1985. Average is for the most recent sampling event for which data are available. No data indicate inability to obtain data on specified parameter for use in this project, and does not necessarily mean that no data exist. *Value in parenthesis is calculated average without data from well G11S.
(1) Based on 1 sampling event of two wells
(2) Data for one sampling event only

site. The spacing between downgradient dolomite monitoring wells varies from 700 to 1200 feet in Area 3, and 500 to 800 feet in Area 4. The well spacings were based on the results of groundwater modeling by Canonie (1985a), which predicted that a plume, originating from a point source on the edge of the site (a worst-case scenario), could be detected by wells spaced 1000 feet apart (fig. 7).

The use of a contaminant transport model to simulate conditions in fractured rock should be undertaken only with extreme caution. The model used by Canonie was based on a chemical transport equation valid for a uniform porous media such as a sandstone. Because proven, available transport models designed for flow in fractured aquifers did not exist, Canonie used a uniform porous media model. Such models generally are inadequate to characterize contaminant migration in fractured media (Faust and Mercer, 1980). For example, if a leak developed near the edge of the facility between wells spaced at a large interval, contaminant migration might not be detected as soon as would be desirable. The modeling consultant justified using the model for this application, citing a rock coring study and a geophysical study (Canonie, 1985b; Technos, 1984) which indicated that the dolomite can be approximated as a uniform porous medium.

The interpretation of the transport model results also is a concern. A Gulf Coast Laboratories, Inc. letter to WMI (Feb. 27, 1985) reports that a plume at 0.2 percent of CID leachate concentration would show a significant increase in specific conductance (100 μmhos/cm, as defined by IEPA) when mixed with ambient groundwater in the dolomite. WMI elected to space its wells so as to enable contaminant detection at the more conservative value of 0.3 percent of source concentration. Detection at this level would require a well spacing of at least 1000 feet, according to the plume modeled by Canonie (fig. 7). Two problems with the results of the CID/Canonie model, however, make the 1000-foot well spacing suspect. The first problem concerns the failure to note a time reference for the plume shown in figure 7. Without a time frame, there is no way of know-

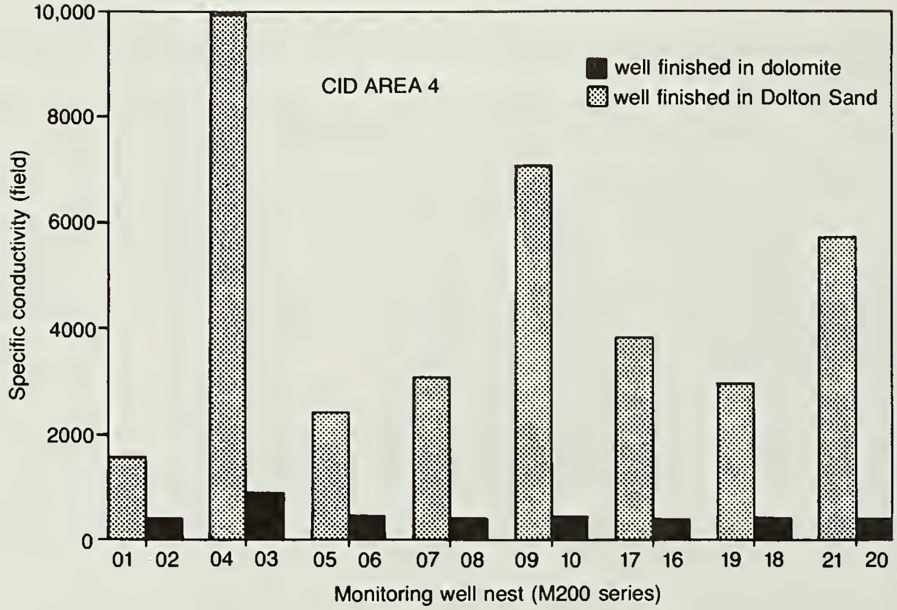

Figure 6 Comparison of specific conductivity values measured at CID, Area 4. Measurements were made August 1984.

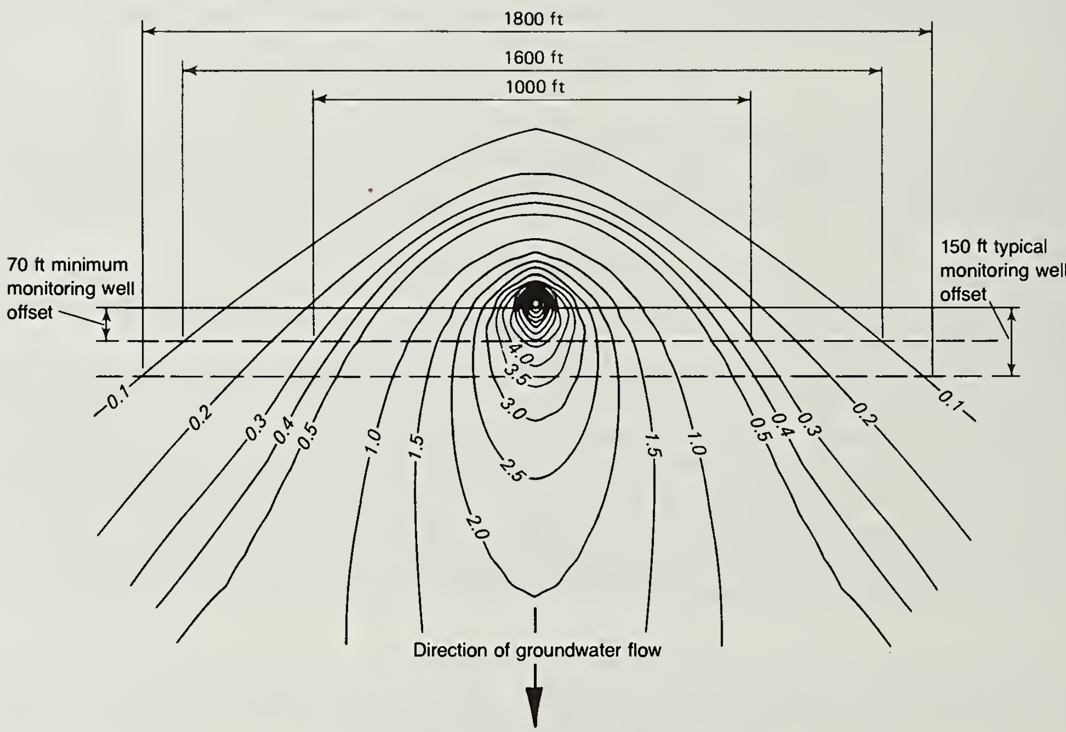

Figure 7 Results of contaminant transport model by Canonie (1985a). Contoured values are the percentage of source contamination from a "worst-case" open borehole leak. Offset is measured from edge of waste disposal area.

ing whether the plume represents 90 days or 90 years of possible contaminant leakage. The second problem concerns interpretation of the model. The model was stopped when the theoretical chloride concentration at the property boundary reached the maximum, allowable concentration for Illinois drinking water standards. However, figure 7 shows, for a worst-case scenario, that the model will predict a fairly large plume of contaminants, at a detectable concentration, several hundred feet past the monitoring wells by the time the detectable part of the plume (0.3 % contour) reaches the monitoring wells. Since all the downgradient monitoring wells at CID are located at or near site property boundaries, the result of this scenario would be off-site contamination. Therefore, if the theoretical modeled case was applied to the CID site, a significant contaminant plume might migrate off site before it could be detected by the wells spaced at large intervals. Based on these two observations, the ability of the CID groundwater monitoring program to detect early contaminant migration in the area of large, well-spacing intervals may be suspect. However, this monitoring well program should be able to detect contamination before the aquifer is seriously degraded.

Sources of Information

Many of the sources listed are from the files of the Illinois Environmental Protection Agency. These documents are generally submitted with permit applications.

Reports

Canonie Environmental, 1982, Leachate-soil compatibility evaluation, CID Environmental Control Center, Chicago, Illinois, 11 p. plus appendix.

Canonie Engineers, 1985a, Assessment of monitoring well system, Area 3 and 4, 32 p. plus appendix.

Canonie Engineers, 1985b, Summary Report: Monitoring well evaluation and installation program, Area 3, CID complex, 6 p. plus appendix.

Colton, C. E., 1985 (draft), Industrial wastes in the Calumet area, 1869-1970, An Historical Geography: Illinois State Museum, Springfield, IL, 138 p.

Faust, C.R. and J.W. Mercer, 1980, Groundwater modeling--Recent developments: Groundwater, vol. 18, no. 6, pp. 569-577.

Technos Inc., 1984, Geophysical Survey--Calumet industrial disposal facility, Cook County, Illinois, 33 p. plus appendix.

Testing Service Corp., 1979, Site exploration boring report, CID landfill, boring logs.

Walter H. Flood Co., 1973 (draft), Soil Investigation No. 7305-0181, CID 134th Street and 194, boring logs.

Walter H. Flood Co., 1975, Soil investigation No. 7505-6104, Chicago/Southeast Land Development and Reclamation Company, boring logs.

Waste Management, Inc., 1985 (draft), Groundwater monitoring program for CID Environmental Control Complex, Illinois facility.

Woodward-Clyde Consultants, 1983, Geologic, hydrogeologic, and geotechnical evaluation of Area 3, 17 p. plus appendix.

Woodward Clyde Consultants, 1984, Geologic and hydrogeological evaluation of the Dolton Sand Layer at Area 4, CID Landfill, Cook County, Illinois, 9 p. plus appendix.

Letters and Memoranda

Illinois Environmental Protection Agency, 1975, February 14 letter, C. E. Clark to WMI: Operating permit for CID landfill.

Waste Management, Inc., 1978, December 8 letter, B. Fowler to IEPA: Application for permit, CID II (Area 3).

Gulf Coast Laboratories, Inc., 1985, February 27 letter to WMI: Results of leachate-water mixing analysis.

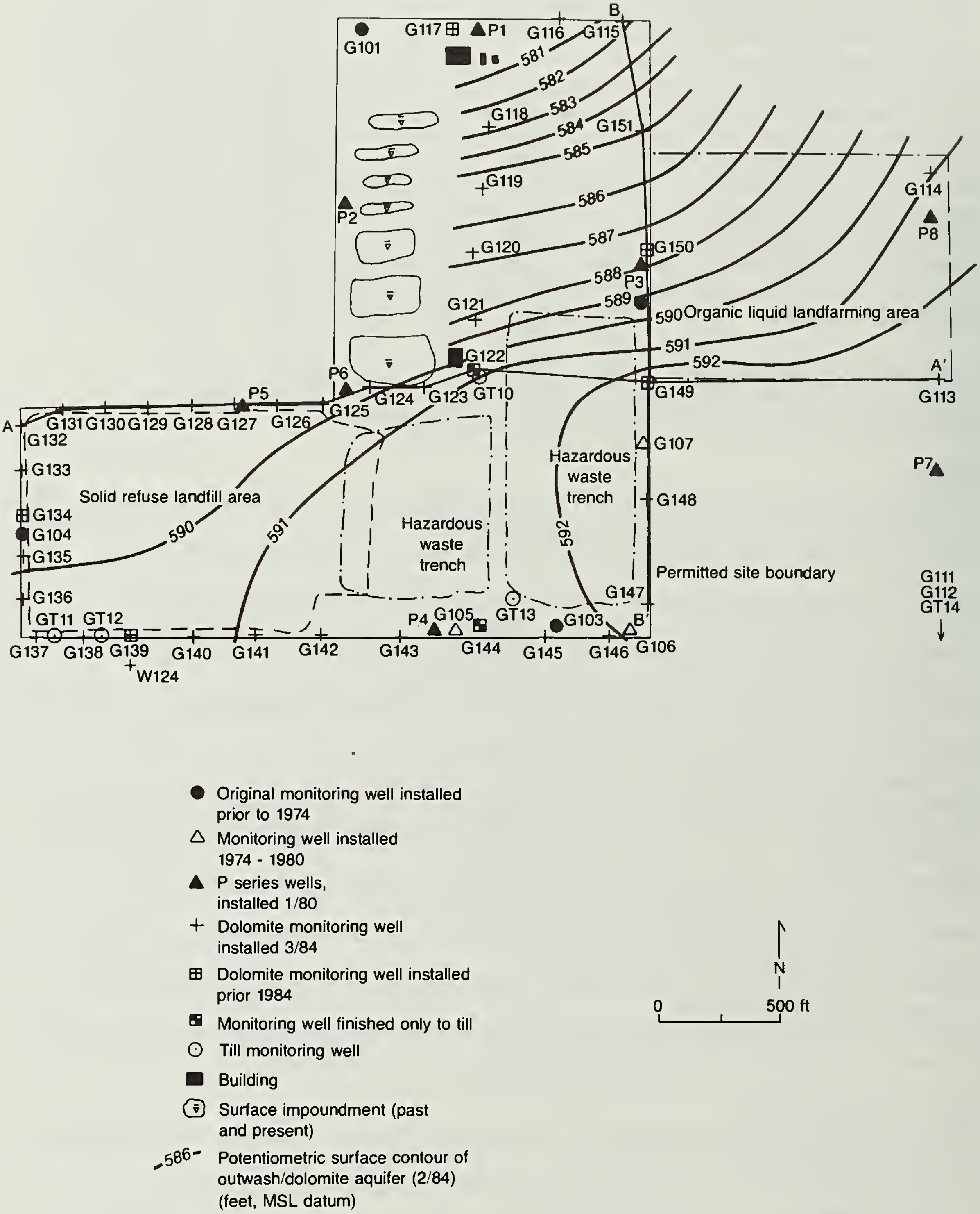

Figure 8 Map of Environmental Sanitary Landfill showing disposal areas, monitoring well locations, potentiometric surface of the outwash/dolomite aquifer, and lines of cross section.

ENVIRONMENTAL SANITARY LANDFILL

Site Description

The Environmental Sanitary Landfill (ESL), located in the N 1/2, Section 31, T35N, R10E, Will County, opened in 1972. Waste Management of Illinois, Inc.(WMI) has owned the site since 1981. The original, 1972 Illinois Environmental Protection Agency (IEPA) operating permit allowed disposal of municipal and industrial waste and dried sewage sludge at the site. Industrial waste, as stated in the 1972 permit, may have included wastes that now would be classified as hazardous. Results from chemical analysis of leachate collected at the site suggest that organic compounds, solvents, and heavy metals were among the wastes disposed of at the site (Canonie 1983). A portion of the site also was used for land-farming of nonhazardous liquid waste; the practice was discontinued in 1981. In 1984 IEPA denied ESL an operating permit for a new disposal trench (Trench 11), which would have expanded the site. The denial was due to possible contamination, in the form of organic compounds, detected in groundwater samples taken at the site. IEPA has requested the USEPA to issue an order for corrective actions at the ESL site.

The ESL site has not accepted any wastes for more than a year. Waste Management of Illinois, Inc. is appealing the IEPA denial of a permit for expansion and hopes to reopen a portion of the site (WMI, 1985a).

ISGS personnel visited the Environmental Sanitary Landfill in June, 1985, but disposal activities were not in progress at the time. The site consists of 11 hazardous waste trenches and a solid refuse landfill area (fig. 8). The trenches and the solid waste area are closed with the exception of one open trench where no wastes have yet been placed. The facility also contains six lagoons (fig. 8), some of which were used to store potentially hazardous rainwater run-off from portions of the site. WMI personnel report that these lagoons have since been certified closed and covered. ISGS personnel noted one large lagoon north of the site and a very large waste gypsum pile west of the site, both of which belong to a nearby chemical company.

Geology and Hydrology

The ESL site is on 110 acres in north-central Will County. The site elevation ranges from 590 feet at the lowest point to more than 660 feet at the summit of the waste disposal mound. Surface water drains toward the Des Plaines River, which has an approximate elevation of 505 feet, 1/3 mile northwest of the site. The elevation of the 500-year flood event of the Des Plaines River is approximately 515 feet (Woodward-Clyde Consultants, 1980), well below the elevation of the site.

Cross sections A-A' (fig. 9) and B-B' (fig. 10) show the relationship of unconsolidated materials to bedrock beneath the ESL site. The upper-most geologic unit at the site is the Yorkville Till Member of the Wedron Formation (Woodward-Clyde Consultants, 1980). The Yorkville Till is an unconsolidated, pebbly clay of glacial origin. Locally, the upper 10 feet of this till contain thin, discontinuous sand lenses (Woodward-Clyde Consultants 1980). The clay minerals in the till are mostly nonexpansive illite chlorite and kaolinite, which are not expected to undergo any appreciable amount of change due to reactions with leachate (Canonie, 1982). The Yorkville Till is 29 to 38 feet thick at the site (Testing Service Corp., 1972); however, trench excavation may have reduced the thickness of this till under the disposal cells to a minimum of 10 feet.

Laboratory tests have indicated hydraulic conductivities of till material in the range of 1.6×10^{-8} to 8.1×10^{-8} cm/s (Woodward-Clyde Consultants, 1983). In-situ permeability tests have also been conducted. Slug tests yielded hydraulic conductivity results of about 10^{-8} cm/s (Woodward-Clyde Consultants, 1983b). However, pump tests conducted on monitoring wells finished in the till yielded hydraulic conductivity results in the 10^{-6} to 10^{-7} cm/s range (Woodward-Clyde Consultants, 1984). Although it is very difficult to conduct accurate pump tests on monitoring wells

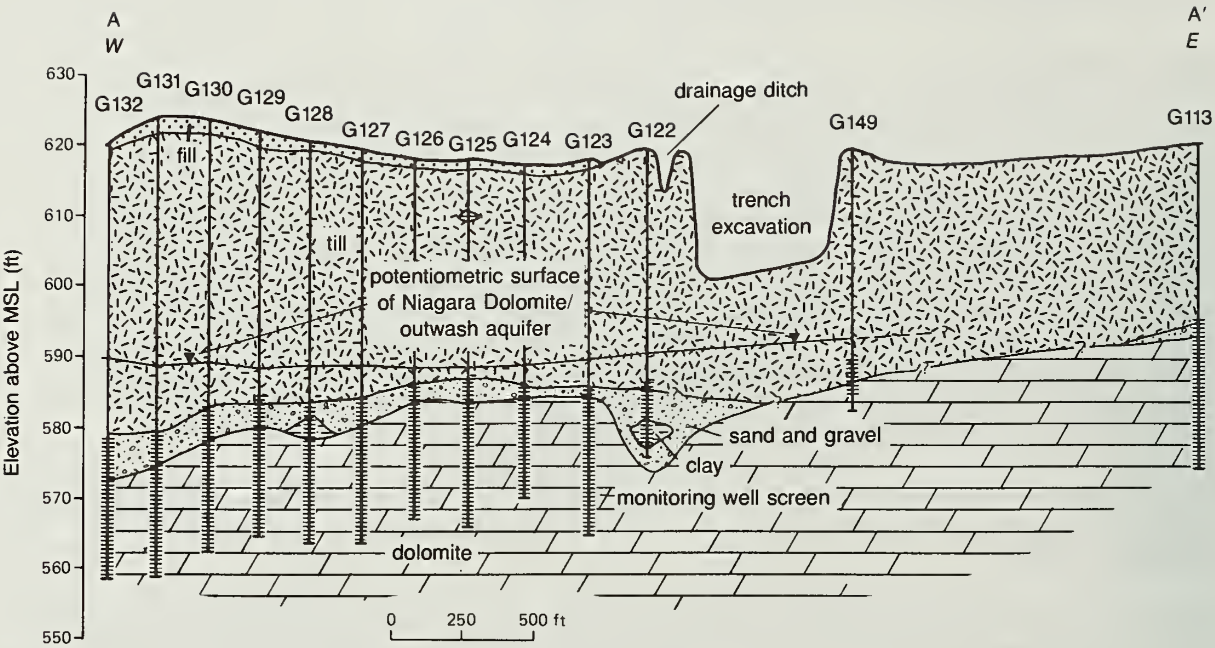

Figure 9 ESL cross-section A-A', west-east along north edge of co-disposal area and through trench area.

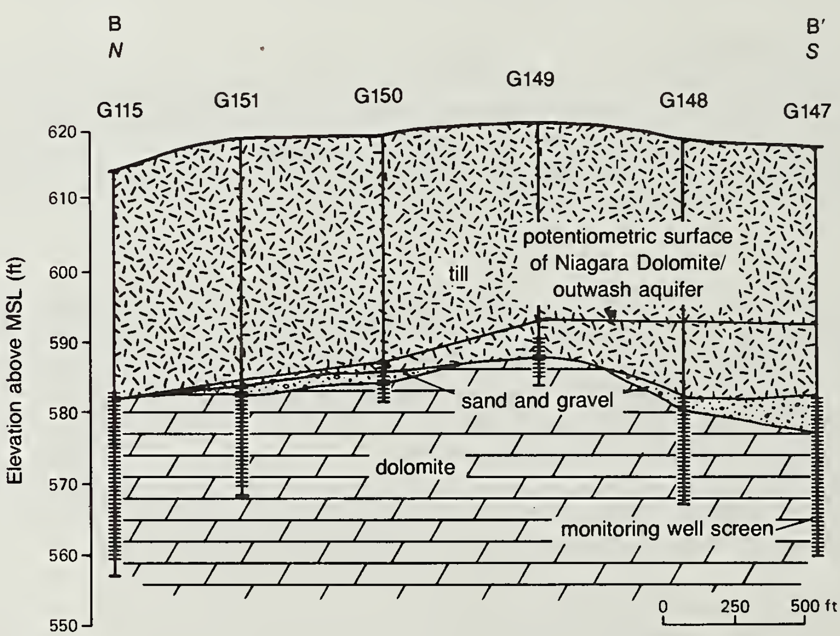

Figure 10 ESL cross-section B-B', north-south along east of site.

finished in tills, field tests are generally more accurate than laboratory tests because field tests sample a larger volume of soil, which may include fractures and other macropores. Significant differences between laboratory and field test results have been observed at other sites in similar settings (Herzog and Morse, 1986). The actual value of the hydraulic conductivity of the till is very important. If the hydraulic conductivity values derived from the lab and slug test are correct, it could require more than 100 years before leachate from the site would reach the dolomite aquifer. If the pump test value of hydraulic conductivity is correct, then fractures may exist in the till and leachate from the site could possibly reach the dolomite aquifer in less than five years.

Underlying the Yorkville Till are sand and gravel (outwash) deposits, possibly of the Malden Member of the Wedron Formation (Woodward-Clyde Consultants, 1982). These outwash deposits are 1 to 11 feet thick beneath the site and reportedly are hydraulically connected to the underlying Silurian Dolomite (Woodward-Clyde Consultants, 1980). Because of this possible hydraulic connection, the outwash deposits and the upper (weathered) portion of the dolomite may be considered a single aquifer. This outwash/weathered dolomite zone is considered to be the uppermost aquifer at ESL; thus, RCRA requires the groundwater in the zone to be monitored for possible contamination.

The Silurian Dolomite bedrock is locally 160 to 200 feet thick. The upper 5 to 20 feet of the unit is highly fractured due to preglacial weathering. Two other moderately permeable zones have been identified in the dolomite. These zones are near the middle and base of the unit, and are reportedly separated by dense, low permeability dolomite. The existence and depths of the permeable zones are based on pressure test data of a nearby boring interpreted by Woodward-Clyde Consultants (1983). The degree of hydraulic connection between the three units is unknown. The hydraulic conductivity of the outwash/weathered dolomite zone ranged from 2.8×10^{-2} to 2.6×10^{-6} cm/s, with many values between 10^{-3} to 10^{-4} cm/s. These values, which are average for fractured dolomite, were determined from pumping tests of monitoring wells by Woodward-Clyde Consultants (1984). Groundwater flow in each zone of elevated permeability is north to northwest (fig. 8) toward the Des Plaines River (Woodward-Clyde Consultants, 1983).

The Silurian Dolomite has been used as a source of water by at least 68 domestic wells in the ESL vicinity. This estimate, by Woodward-Clyde Consultants, (1980), does not include wells north of the Des Plaines River. The Silurian Dolomite aquifer is partially separated from the underlying, high-yield Cambrian-Ordovician aquifer by approximately 100 feet of low hydraulic conductivity Maquoketa Shale. In addition, the dolomite aquifer is penetrated by at least 13 wells which pump water from the deeper Cambrian-Ordovician aquifers (Woodward-Clyde Consultants, 1980). The Cambrian-Ordovician aquifer is a major source of water to the City of Joliet.

Groundwater Monitoring History

When the ESL site opened in 1972, the original IEPA permit required the installation of four monitoring wells. Only two of the wells were downgradient of the waste disposal areas. Three more wells, added to the site later, were not located downgradient. In addition, boring logs or installation reports do not exist for any of these wells. Five of the seven wells were later found to be finished in till rather than in water-yielding zones. Data from the other two were insufficient to determine where they were finished.

In 1982 ESL upgraded its old monitoring system with eight new monitoring wells (the P series). The new wells were located so that four may be considered to be downgradient of the site, making a total of six possible downgradient wells. Only one of the downgradient wells was located west of the waste disposal area, but questionable development techniques were used for this well. WMI personnel report that some of these wells are still active.

WMI implemented a new monitoring system in 1984. The system includes 41 wells finished in the outwash/weathered dolomite and five wells finished in the till. The wells in the outwash/weathered dolomite are at the periphery of the property and are spaced approximately 180

Table 6 Chemical parameters analyzed in water samples taken quarterly from monitoring wells at the ESL site.

	Indicator parameters	*Specific organic compounds*
All wells	pH (field)	Benzene
	Specific conductance (field)	Methyl ethyl ketone
	Total organic halogen (TOX)	*Methylene chloride
	Total organic carbon (TOC)	Tetrachloroethylene
	Chloride (Cl)	*Toluene
	Iron (Fe)	*1,1,1-Trichloroethylene
	Manganese (Mn)	Tetrachloroethylene
	Sodium (Na)	Xylene
	Sulfate (SO_4)	*Phenol
Till wells only	Boron (B)	*1,1- Dichloroethane
		*1,2-Dichloroethane
		Ethyl benzene
		Ethyl acetate
		Trichlorofluoromethane

*Organics detected in leachate, pumped directly out of ESL trenches, at concentrations greater than 500 µg/L (Canonie, 1982).

to 260 feet apart downgradient of the disposal areas, and 220 to 550 feet apart upgradient (fig. 9). In addition, five wells in the dolomite and one in the till were located off-site for monitoring of background groundwater quality.

Figure 11 shows the typical well construction used at the ESL site. The monitoring wells finished in the till are 15 to 27 feet deep. All till wells are constructed with 4-inch ID PVC pipe and screen, with screen lengths of 5 to 10 feet. The deeper outwash/dolomite wells are 24 to 65 feet in depth. There are two types of deep wells, differentiated by installation date. The older wells (G111, G117, G122, G134, G139, G144, G149, G150) were installed in 1983 with 4-inch ID PVC pipe and screen; the newer wells have 2-inch ID PVC pipe and screen. All wells were reportedly sealed with bentonite-cement grout and have flush-thread PVC couplings. Well intake screen lengths in the outwash/weathered dolomite vary from 5 to nearly 30 feet. Twenty of these monitoring wells have screens more than 19 feet long. Only 15 wells have screens less than 10 feet long.

Table 6 lists the parameters monitored in water samples taken from ESL monitoring wells, as specified in the 1984 IEPA permit. Most of the compounds found in high concentrations in ESL leachate (Canonie, 1982) are monitored. Groundwater monitoring has been conducted on a quarterly basis at ESL since at least 1980. Information on monitoring results prior to 1980 is incomplete.

Late in 1980, concentrations of chlorine, manganese, phosphorus, sulfate, and phenols measured in samples taken from the original series of monitoring wells were found to exceed state water quality standards (IEPA, 1981). These measurements may be suspect since the wells may be poorly constructed and finished in till. In addition, organic compounds have been detected in many of the 1984 monitoring wells. Since late 1984, 19 of the 1984 series wells on-site have had detectable amounts of organics determined on two of the three sampling occasions (IEPA, 1985). However, all but two of the wells also have had one sampling occasion when organic compounds have not been detected. Therefore, the significance of these "detects" is questionable.

The Water Quality Analysis master file at IEPA contained chemical analyses for six indicators of groundwater contamination for the ESL monitoring wells. The six indicators are specific conductance, residue on evaporation, chloride, phenols, total organic carbon, and total organic halogen.

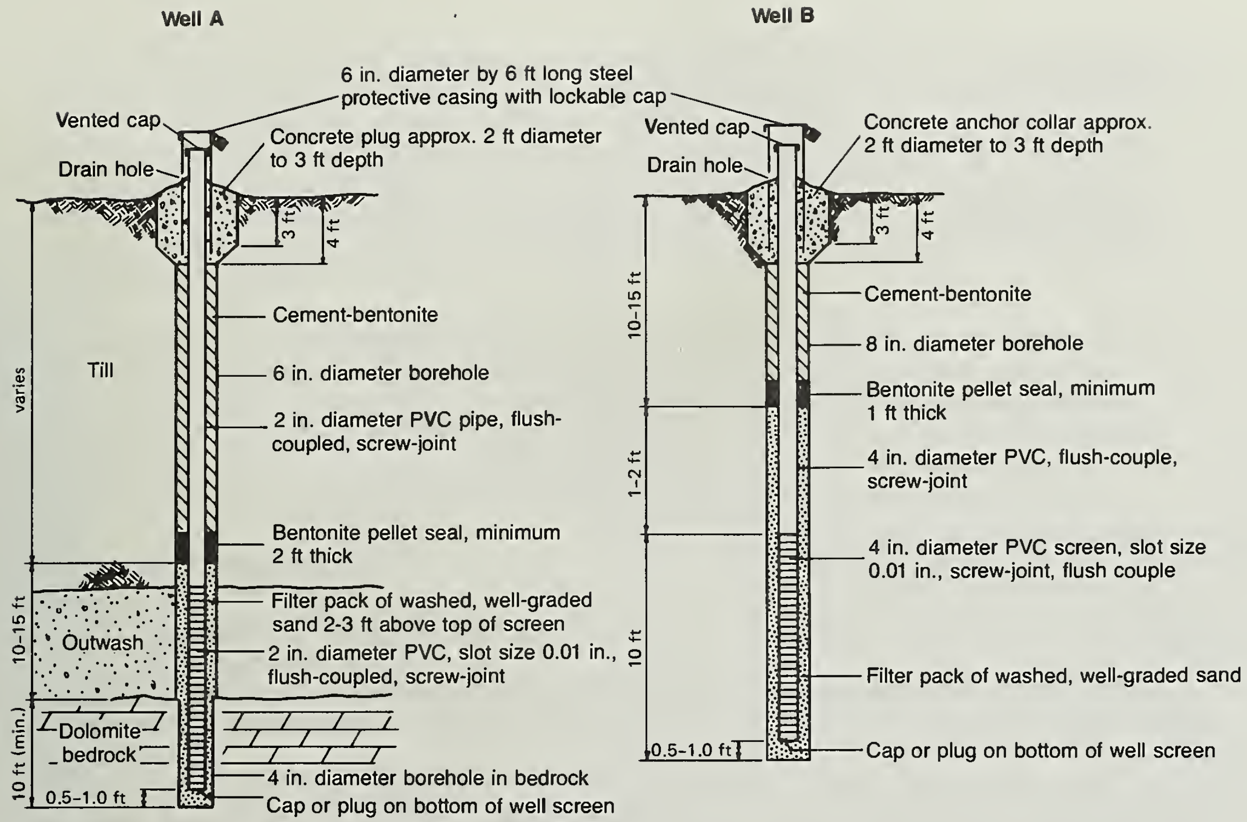

Figure 11 Typical construction of bedrock (A) and till (B) wells at ESL site.

Data existed for sampling events between April 1984 (the first sampling event to utilize the 1984 series wells) and May 1985. In addition, limited data were listed for the older wells dating back to 1973. Wells G101, G102, and G104 showed increases in both chloride and ROE concentration since 1974. It is impossible to determine the significance of the increases, however, because little is known about the construction and finished depths of the wells.

Chemical data from the 1984 series wells for the period, April 1984 to May 1985, were averaged and plotted on a site map. The procedure revealed two areas of anomalously high ROE and specific conductance (SC) values. The highest values were mapped at wells G115-G118 (fig. 12). These wells, along the north boundary of the site, are downgradient of the waste disposal areas. The ROE and SC values decrease towards the waste areas. A second anomalously high area of ROE and SC values was detected at wells G127-G130 (fig. 12). This area coincides with well P5 (fig. 8), discussed in the next section. There are no available data to conclusively explain these groundwater quality anomalies.

Evaluation of Groundwater Monitoring Program

The groundwater monitoring program at ESL has been upgraded several times since 1972. Deficiencies in past monitoring programs resulted from inadequate regulatory and well construction practices. Of the original four monitoring wells, only two were located downgradient of the waste disposal cells. One of the downgradient wells was located nearly 3,000 feet from the disposal area. IEPA specified the locations for these four wells in the original 1972 operating permit.

Well logs and installation records do not exist for any monitoring wells installed prior to 1980. It was later discovered that most of these wells were not finished in the uppermost aquifer, the outwash/ weathered dolomite zone.

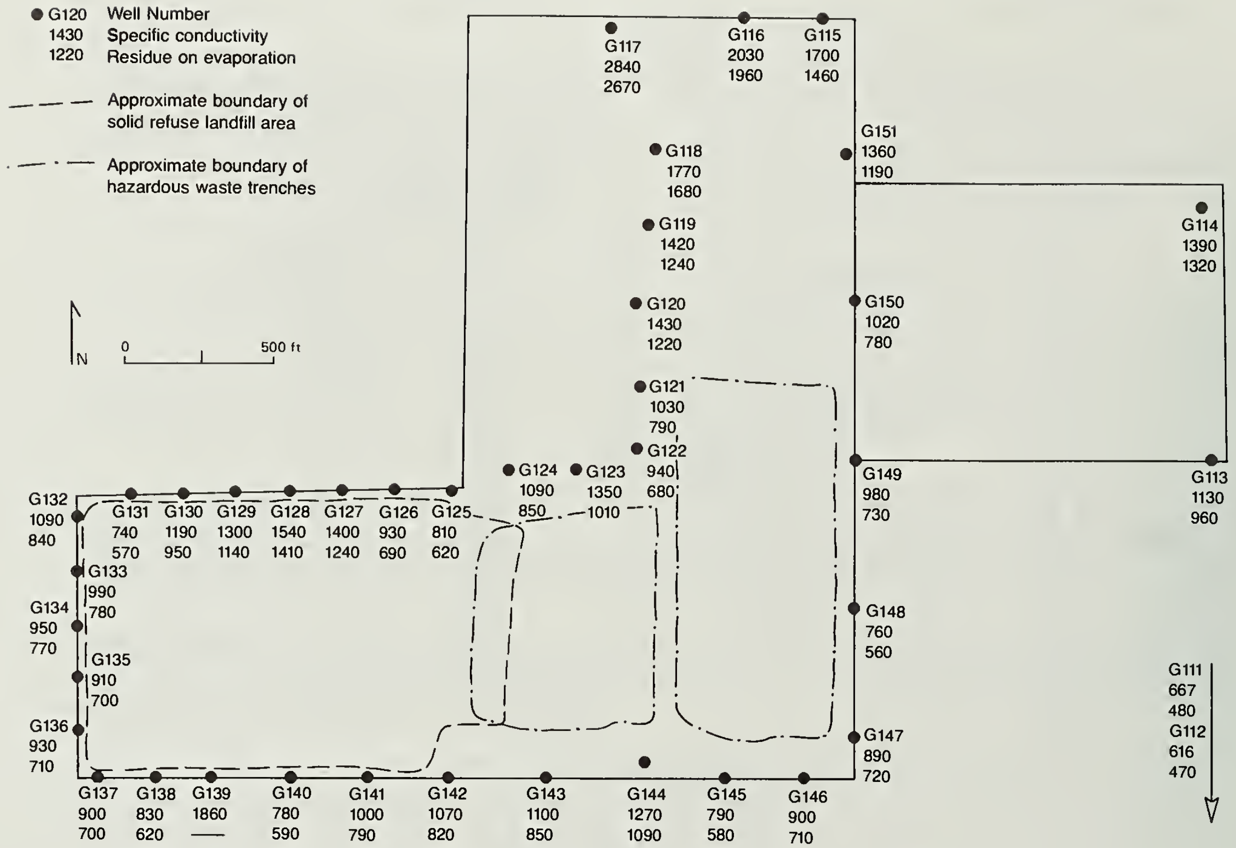

Figure 12 Map of specific conductivity and residue on evaporation values for water samples from ESL monitoring wells. Values are average of all readings at each well between April 1984 and May 1985.

IEPA deemed the P series monitoring wells, installed in 1982 to satisfy the Resource Conservation and Recovery Act (RCRA), "incapable of adequately determining the facility's impact on the quality of the groundwater in the uppermost aquifer underlying the site" (IEPA, 1983). Stated deficiencies were that the "well number, locations, and depths do not insure prompt detection of hazardous waste constituents that may migrate from the waste management area." Water samples from one well (P5) located directly north (downgradient) of the solid waste site had high total organic halogen (TOX) values (P.E. LaMoreaux, 1984). WMI believes well P5 may have been constructed using glue to seal the PVC pipe joints (WMI, Personal Communication, 1985b). If the joints of the well are glued, the high TOX values may be attributable to organic compounds leached from the glue.

The latest series of groundwater monitoring wells, added in 1984, appear to be adequate regarding the number and spacing of wells and the parameters analyzed. However, ISGS noted three possible deficiencies in the groundwater monitoring program. Two wells (G122 and G144) intended to monitor the outwash/weathered dolomite zone are not finished in this zone. According to boring logs, well G122 is finished in the upper outwash (see fig. 9) and well G144 is finished in the till. These wells, judged by the operator to be in noncritical areas, have not been replaced.

Another concern with the present monitoring system may be the length of the well screen in numerous monitoring wells. Screens for many ESL wells exceed 24 feet in length. WMI person-

nel report that the long screen lengths were used to ensure that the entire thickness of the permeable zone would be sampled and that an adequate volume of sample could be obtained. In theory, it is possible that the chemical analyses of samples from these wells would not be able to detect contamination due to dilution of the contaminant with ambient groundwater. Low concentration of organic compounds, however, have been detected in samples obtained from the monitoring wells at the ESL site. Thus, the conclusion may be made that the groundwater monitoring system at ESL is able to detect the migration of contaminants from the site even with the long screen lengths.

Perhaps the most significant problem with the groundwater monitoring system at the ESL site is the lack of historical data. The present monitoring system, although adequate in the number, placement, and spacing of wells, is incapable of determining the source of high indicator value concentrations due to insufficient historical data. There is no way to know whether high indicator values are a result of ESL landfilling activities or another source because information on the quality of the local groundwater before the initiation of landfilling operations does not exist.

Sources of Information

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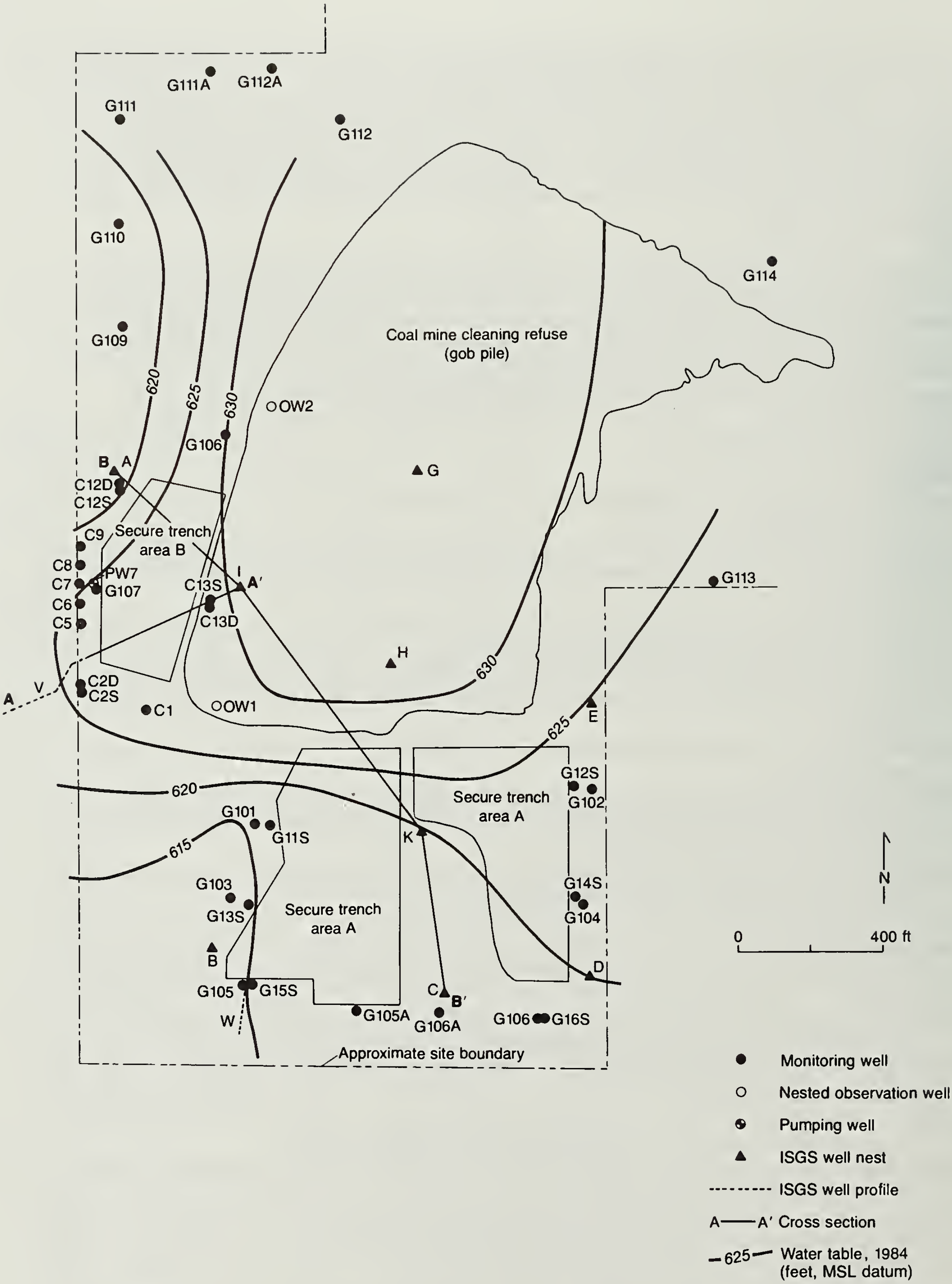

Figure 13 Map of SCA Services, Inc.-Wilsonville showing disposal areas, well locations, water table elevation, and lines of cross section (from Geoengineering, 1982).

SCA SERVICES, INC.-WILSONVILLE

Site Description

The SCA Services, Inc.-Wilsonville (formerly Earthline) site is located immediately south of the Village of Wilsonville in southeastern Macoupin County in Section 10, T7N, R7W. The 130-acre site began operation, using a trench and fill procedure, on November 15, 1976 under an IEPA operating permit (IEPA, 1976). More than 85,000 barrels and other containers with more 6 million gallons of industrial wastes were disposed of in 26 trenches in two separate disposal areas covering approximately 11 acres (fig. 13). These wastes included materials from the following industries: chemical, iron/steel foundry, photofinishing, fertilizer, plating/polishing, utility companies, paper/printing, and military/ammunition (USEPA, 1982). Several months after the site opened, the citizens of Wilsonville, alarmed at the disposal of hazardous wastes near their community, filed a suit to stop the disposal of wastes and have the wastes exhumed. During the lengthy court battle, Earthline continued to bury wastes at the site. In March 1981, the Illinois Supreme Court affirmed a 1978 ruling that buried wastes should be exhumed and removed from the site. Preparations for exhumation began the following summer; the actual removal began September 7, 1982. All waste was removed before the end of 1987. Earthline was absorbed by its parent company, SCA Services, Inc., coincidental to the excavation at the Wilsonville site.

In December 1981, routine groundwater monitoring revealed contamination in a monitoring well near Trench Area B (fig. 13). Remedial action in the form of a pumping well began the following January. Shortly thereafter, the ISGS initiated a study of contaminant migration at the site, under cooperative agreement with the USEPA, to determine why the contaminants moved faster than expected. The ISGS study included a detailed review of the site geology and the installation and monitoring of an independent set of monitoring wells and piezometers. This earlier involvement familiarized the ISGS with the geology and groundwater quality of the SCA Services, Inc. site, making a special visit to the facility for this study unnecessary.

Geology and Hydrology

A 1975 Illinois State Geological Survey preliminary hydrogeologic evaluation describes the site as having unconsolidated glacial drift that ranges in thickness from less than 50 feet to more than 100 feet. The drift mainly consists of a pebbly clay material, called till, with interbedded sand and gravel layers. While subsequent studies have added detail to this description, the ISGS summary of geologic conditions at the site remains valid.

A brief description of geologic units encountered at the site, based on reports by Geoengineering, Inc. (1982) and Follmer (1984), follows. The cross sections in figures 14 and 15, based mainly on logs from the ISGS study, show the geologic units and their relationships. The ISGS logs were used because they were based on continuous samples of the material.

The first unit encountered at the land surface is the modern soil developed in the Peoria Loess. It is orange-brown and varies in thickness across the site. The Peoria Loess here is weathered, clayey silt, and nearly 4 feet thick. Beneath the Peoria Loess is the Roxana Silt, also weathered (Farmdale Soil). It has a higher sand content (1 to 3 feet thick) than the Peoria Loess. Underlying the Roxana Silt is the Vandalia Till, divisible into four parts (in descending order): a brown, weathered clay-rich zone; a soft, weathered zone; a brown, brittle, partly weathered, jointed zone; and a gray, unweathered, massive zone. The weathered part represents the Sangamon soil and ranges from 8 to 12 feet in thickness at the site. Discontinuous sand lenses are widely scattered through the Vandalia Till, but are more common at the base of the unit. The Vandalia Till below the Sangamon Soil typically ranges from 5 to 20 feet in thickness. The Vandalia Till overlies older tills of the Banner Formation (Follmer, 1984). The thickness of the Banner Formation is unknown at most locations, since few borings penetrated its thickness. One boring near the center of the site encountered nearly 50 feet of the Banner Formation. Laboratory tests of the hydraulic con-

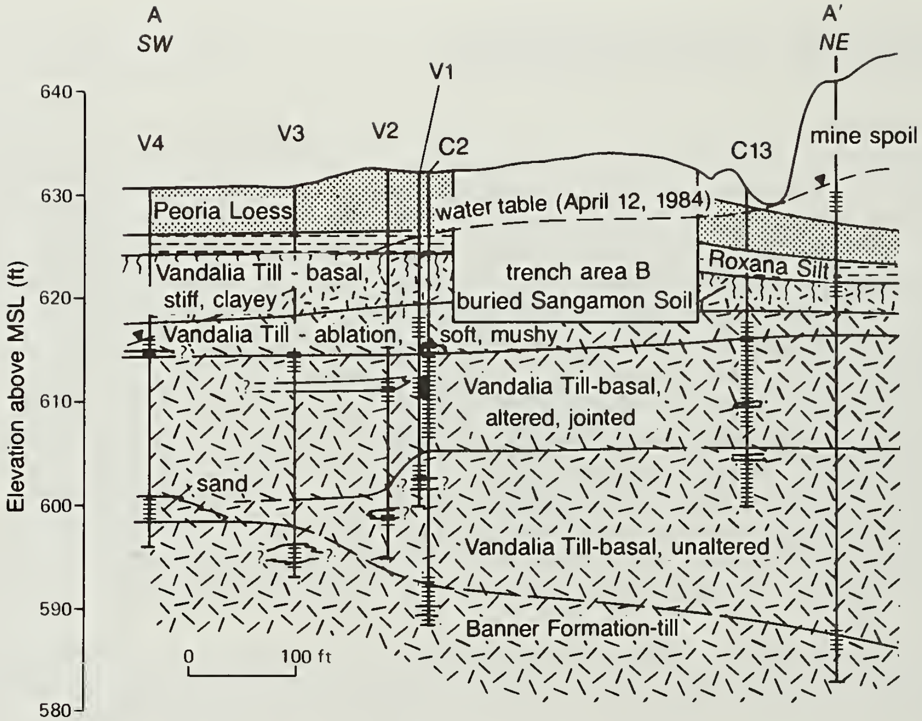

Figure 14 SCA Services, Inc.-Wilsonville cross section A-A', southwest-northeast through secure trench area B.

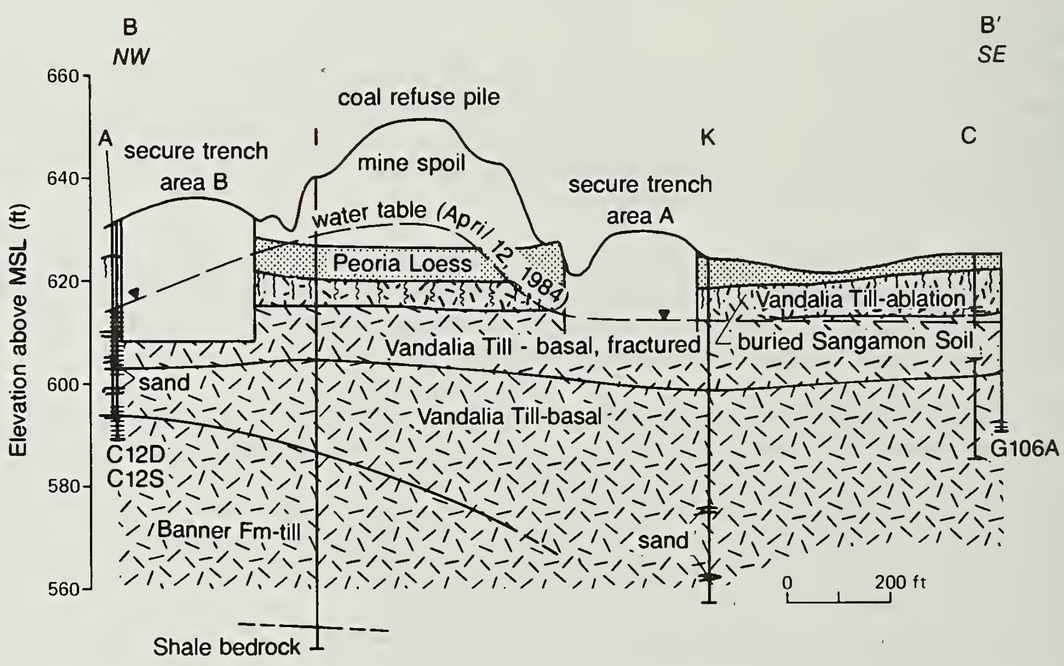

Figure 15 SCA Services, Inc.-Wilsonville cross section B-B', northwest-southeast through secure trench areas A and B.

ductivity of the tills were performed before the site opened. They produced values of approximately 1 x 10^{-8} cm/s for the clayey, weathered zone and the unaltered till zone (Mathes, 1976). These values were so low that the till was said to be essentially impermeable. Laboratory tests by Geoengineering (1982) and the ISGS (Herzog and Morse, 1986) later verified the earlier results. Field slug and recovery tests performed by the ISGS indicated values 100 to 1000 times greater than those produced in the laboratory, however (Herzog and Morse, 1986). The ISGS scientists believe the higher hydraulic conductivities measured in the field are due primarily to joints in the till. Groundwater is able to migrate more rapidly through the jointed material than through the till matrix. Since the original contaminant travel-time predictions were based on the laboratory test values, the higher field values could explain why the contaminants moved so much faster than expected.

A large pile of coal mining waste near the center of the site controls groundwater movement at the site. Groundwater flows radially away from this waste pile (fig. 13). The water table is approximately 10 to 20 feet below the ground surface in the vicinity of the disposal areas (figs. 14 and 15). No known aquifers underly the site within 200 feet of land surface and no known water supply wells are within 1/4 mile of the site. Therefore, no "uppermost aquifer" has been defined for monitoring purposes. Wilsonville residents obtain water from a reservoir near Gillespie, approximately 5 miles away. Monitoring wells at the site, therefore, are finished in the fine-grained till or in isolated sand lenses within the till.

Groundwater Monitoring History

The original groundwater monitoring plan (see fig. 33) called for the installation of 14 monitoring wells (G100 series) constructed of PVC plastic pipe with glued joints. These wells were supposed to surround the proposed trench area (Andrews, 1976). Well installation was to proceed as trenching activities moved into new parts of the site. One well was to be placed in a position that was obviously upgradient. All the wells were installed at about the same time (before disposal began) and fewer trenches were installed than planned. This caused four wells to be placed in areas where no disposal occurred. Most of these original 14 wells were finished in the Vandalia Till at depths between 30 to 50 feet.

The IEPA operating permit (IEPA, 1976) required the six wells downgradient from active trenches to be monitored quarterly for total dissolved solids (TDS), chemical oxygen demand (COD), cadmium, chromium, and zinc. The permit also stipulated that analyses for arsenic, copper, cyanide, mercury, and phenol occur on a rotating basis, one per quarter. The two original upgradient wells were to be monitored quarterly for COD, TDS, and oil. Analyses of background levels of PCBs (polychlorinated biphenyls) in the groundwater were required before the site opened. Earthline also analyzed groundwater samples for several trace metals, major anions, and major cations.

In late 1977, the IEPA and Earthline agreed that a shallow groundwater monitoring program was needed. Earthline installed six shallow wells (G11S-16S) in February 1978 to monitor water quality in the Sangamon Soil. The new wells were paired with six of the earlier deep wells to provide information on vertical contaminant migration. Water from both shallow and deep wells was monitored for the same parameters. By late 1980, samples from the wells were also analyzed for PCBs and chlorinated hydrocarbons. Two nests of wells (OW1 and OW2), each consisting of five wells at different depths, were added near the center of the site in August 1981.

In December 1981, routine monitoring confirmed contamination of groundwater by organics in one of the original wells (G107) on the west side of the site near Trench Area B. Well G107 has a 3-foot screen which intersects a thin sand lens in the Sangamon Soil/Vandalia Till zone. Table 7 presents the results of the organic chemical analyses performed by the IEPA for the G-series wells in December 1981 and January 1982. Although organic compounds were in many of the samples, only well G107 contained more than 1 mg/L (milligrams per liter) of more than one compound on either sampling date. The IEPA collected the second set of samples after the installa-

Table 7 Results of positive water quality analyses for organic compounds from G-series wells in December 1981 and January 1982, as analyzed by IEPA

	Well number									
	G101	G11S	G105[1]	G15S	G16S	G107	G108	G12S	G114	G14S
Compound										
Aliphatic hydrocarbons	—	—	560	15--ND	80--ND	97,000--ND	—	—	50	—
Bromochloroethane	—	—	—	—	—	170,000--130	—	—	—	—
Bromochlorocyclohexane	—	ND--20	—	—	—	—	—	—	—	—
Carbontetrachloride	—	—	—	250--48	—	—	—	—	—	—
Chloroform	—	—	—	230--91	—	—	—	—	—	—
Dibromochloromethane	—	—	35	—	ND--3	32,000--67	—	—	22,000	—
Dibromochloropanol	—	—	900	—	60--ND	180,000--140,000	—	—	50	—
Dibromoethane	—	—	—	—	—	8,800--10,000	—	—	—	—
1,1-Dichloroethylene	—	7--20	—	—	ND--4	—	72	—	—	5--ND
1,2-Dichloroethane	—	18--ND	10	—	ND-13	360,000--240,000	—	—	—	—
1,2-Dichloroethylene	—	3--19	—	—	ND--5	—	—	—	—	—
2-Heptanone	—	ND--700	—	—	—	—	—	—	—	—
Hexachloroethene	—	—	120	—	—	32,000--98,000	—	—	—	—
Hydroxymethylpentonone	—	ND--990	—	—	—	—	—	—	—	—
Methylene chloride	—	1,300--380	—	—	—	—	—	27--15	—	—
Pentachloroethane	—	—	—	—	—	690--2,100	—	—	—	—
Tetrachloroethane	—	—	—	—	—	1,100--400	—	—	—	—
Tetrachloroethylene	—	ND-- 1	200	—	—	31,000--24,000	29	ND--1	—	—
Toluene	—	ND--840	—	—	—	—	—	—	—	—
Trichloroethane	—	—	—	—	81--ND	160,000--17,000	—	—	—	—
Trichlorethylene	—	—	4	—	ND--16	—	—	15--ND	—	—
Trimethylcyclohexonone	—	ND--200	—	—	—	—	—	—	—	—
Trimethylfuranome	—	ND--220	—	—	—	—	—	—	—	—
Xylene	—	ND--240	—	—	—	—	—	—	—	—
Unidentified compounds	ND--~120	ND--3,500	~1,300	—	—	~26,000--~92,000	—	—	~150	—

Concentrations are given in μg/L (micrograms per liter or parts per billion). Where two values are recorded, the first is for December 1980 and the second is for January 1982. ND means organic compound was not detected. (—) indicates below detection level.

[1]Well sampled both months, but no organic compounds were found in January 1982.

tion of pumping well PW7 as a remedial measure to remove the contamination found in G107. In December 1981 and January 1982, Earthline added the C series of twelve wells near Trench Area B. These wells have 10-foot screens which approximately span the interval screened by G107. The deeper wells (C2D, C12D, and C13D) have 5-foot screens beginning about 10 feet below the bottom of G107. Figure 16 illustrates the design for these wells. The wells were immediately sampled for volatile organics. Water samples from six of the new wells contained volatile organics; however, the concentrations were much lower than those found in well G107. This indicates that G107 was located near the center of the contaminant plume. Table 8 shows the positive results from these wells and the pumping well. There was no analysis record for C7, one of the wells closest to G107. Wells C5-8 and G125, which monitor sand lenses, were sampled at the end of January, after pumping began in PW7. This may partially account for the newer wells having lower concentrations than G107.

Earthline installed four more wells (G100A series) around the site in April 1982, bringing the total number of monitoring wells to 46. Twenty are upgradient of the trenches. Water quality analysis is currently performed on 36 wells, 26 of which are downgradient. The groundwater monitoring program has retained emphasis on the analysis of organic compounds.

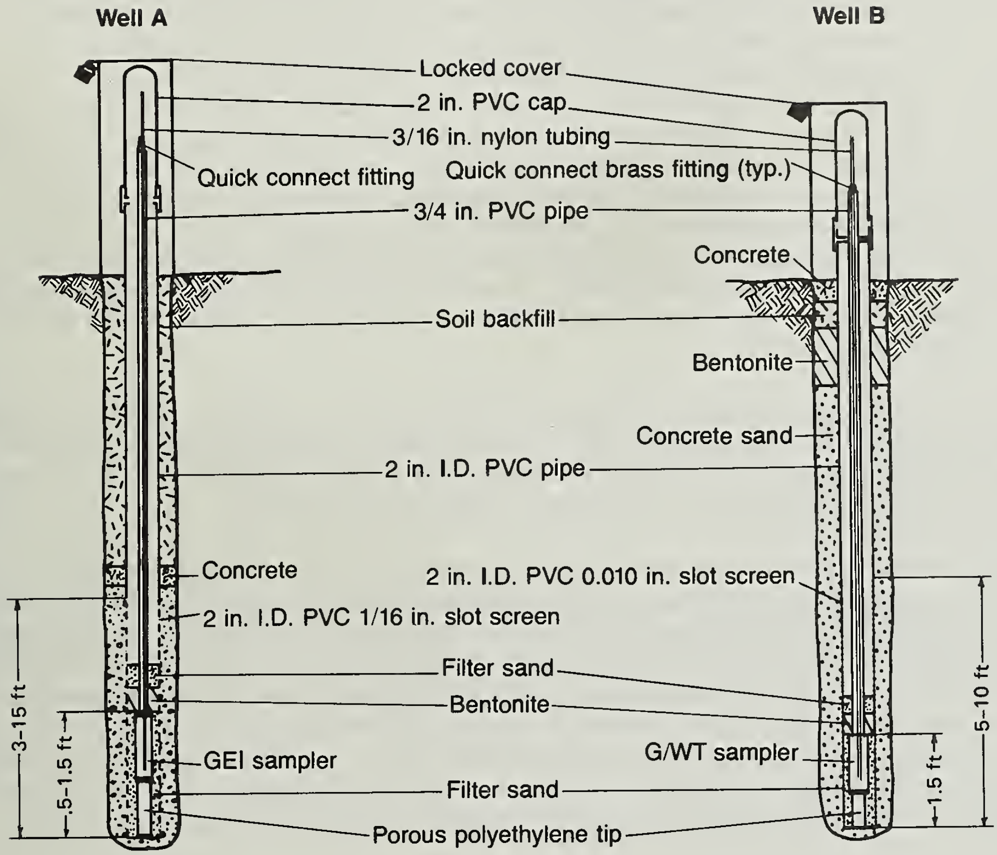

Figure 16 Typical construction of monitoring wells at SCA Services, Inc.- Wilsonville. Well A is representative of the G series; Well B typifies the C series. Wells are not drawn to scale. (From Geoengineering, 1982.)

Table 8 Results of positive water quality analyses for organic compounds in C-series wells and pumping well at Wilsonville

	Well series						
Compound	***C6***	***C8***	***C9***	***C12S***	***C12D***	***C13S***	***PW7***
Dibromochloromethane	—	1,100	—	—	—	—	22,000
Dibromochloropropane	—	—	—	—	—	—	27,000
1,1-Dichloroethane	—	—	—	—	—	—	—
1,2-Dichloroethane	5	760	76	80	350	5	300,000
Dichloromethane	5	140	89	76	22	12	—
Tetrachloroethylene	—	—	—	—	—	—	480
Trichloroethylene	—	6	—	—	—	—	340

Performed by the IEPA January 1982 (concentrations in µg/L).
Note: No data available for C7

The ISGS research program involved the installation of ten sets of nested wells and piezometers (A to I, and K; F is a background well located east of G114 beyond the map boundary in fig. 13) and two well profiles (V and W), for a total of 60 stainless steel or screw-joint PVC monitoring wells and 29 open-hole piezometers. The well profiles consist of two to four clusters of wells located along a line perpendicular to the trench boundaries. ISGS discovered organic contaminants in nests A, B, and K and profiles V and W, with the greatest concentrations in the wells at nests B and W1. At nest B, shallow and deep wells monitoring the Vandalia ablation zone and the fractured Vandalia Till, respectively, showed high contamination levels. The shallow well at nest B produced a sample in December 1984 that contained 1.7 percent Dieldrin pesticide and more than 22 percent Endrin pesticide. Concentrations did not exceed 10 mg/L for any compound found in the other ISGS wells. Trichloroethylene levels in profile V typify values found for volatile organic compounds along in the profile. Figure 17 shows the trichloroethylene plume for September 1984, when the entire profile was sampled. The compound was found only in trace levels in samples from nest V3.

In February 1986, the site proprietor, in cooperation with the ISGS, included 23 of the ISGS wells in its monitoring program on a one-time basis. The evaluation of water samples from both the ISGS and SCA wells, which were collected simultaneously and analyzed by the same laboratory, provide the most complete picture of groundwater quality at the site to date.

The data for volatile organic compounds and organic chemical indicator parameters given in tables 9 and 10 reflect the exhumation activities. Results from the SCA wells presented in table 9 can be compared with values in tables 7 and 8 to show water quality changes during four years. Volatile organic compounds now are found all along the west edge of Trench Area B. Well G107, however, which had prompted the installation of the pumping well, showed a considerable improvement in water quality. This improvement in G107 is probably attributable to the pumping of well PW7 followed by the removal of the contamination source. The higher values in the C-series wells along the west property boundary may indicate either a slower rate of chemical migration from trenches toward those wells or the spreading of the contaminant plume corresponding to G107.

The highest contamination levels are in the southwest part of the site in wells G105, W1D, and B1D, where Endrin and Dieldrin pesticides are present in concentrations greater than 1 percent. The deeper wells at these locations are more contaminated than adjacent shallower wells. This indicates that contaminant migration at this part of the site is more vertical than horizontal, possibly due to the fact that the predominant orientation of the discontinuous fractures is vertical. In addition, Endrin and Dieldrin are heavier than water and tend to sink. Vertical flow was increased by water ponding in the open trench after the waste was exhumed, driving groundwater flow downward. Burial of bulk and liquid wastes in the southwest corner of Trench Area A may account for the high levels of contamination found in the adjacent wells.

Indicator values in tables 9 and 10 show that total phenolics alone is not an accurate indicator of the presence of volatile organic compounds. While the four most contaminated wells produced the highest phenolic values, 11 other wells with lower levels of volatile organic compounds would have gone undetected if phenolics were the only parameter measured. COD (chemical oxygen demand), which was only analyzed for SCA G-series wells, produced positive results for all wells which contained volatile organic compounds. COD did not accurately indicate the degree of contamination of the wells, however.

This data will be used to further improve the groundwater monitoring program at the Wilsonville site. Improvement is necessary to determine the extent of contamination and to measure the success of the clean-up operation. A new monitoring program is planned for after the completion of waste exhumation.

Table 9 Volatile organic chemical concentrations identified in samples taken from SCA wells in February 1986

	Well number																
Compound	G103	G105	G107	G111	G112	G111A	G12S[2]	G15S	G16S	C2S	C5	C6	C7	C8	C9	C12S	C12D
Benzene	—	—	—	—	—	—	—	—	—	4.6	—	—	—	—	—	—	—
Carbon tetrachloride	—	13,400[1]	—	—	—	—	—	22.9	—	40.1	—	—	—	—	—	—	—
Chlorobenzene	—	—	—	—	—	—	—	—	—	12.9	—	—	—	—	—	—	—
Chloroform	—	3,900[1]	75.0	—	—	—	—	384.5	—	14.0	—	—	337	11.8	—	—	—
Dichloromethane	—	11,000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2-Dichloroethane	—	—	14,780	—	—	—	—	—	—	—	410.7	36.4	9150	2460	195.8	6560	5700
1,1-Dichloroethylene	—	—	—	—	—	—	—	—	—	—	—	—	250	3.0	—	—	—
Ethylbenzene	—	141.0[1]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Methylene chloride	8.1	—	25.7	19.1	13.8	16.7	21.0[1]	—	—	—	—	—	—	11.2	—	—	—
1,1,2,2-Tetrachloroethane	—	—	244.0	—	—	—	—	—	10,753	—	—	—	—	—	—	—	—
Tetrachloroethylene	—	—	63.0	—	—	—	—	—	—	10.5	—	—	—	—	—	—	—
Toluene	—	144.0[1]	40.4	—	—	—	—	—	—	—	—	—	294	294	—	—	—
1,1,1-Trichloroethane	—	—	—	—	—	—	—	—	701	—	12.5	—	205	—	—	—	—
1,1,2-Trichloroethane	—	—	4067	—	—	—	—	—	—	—	—	—	302	390	12.2	33.0	31.0
Trichloroethylene	—	127.0[1]	93.8	—	—	—	—	—	—	5.4	—	—	133	9.8	—	—	—
Phenolics, total	NA	120	120	—	—	—	—	NA	—	—	—	—	—	—	—	—	—
COD (mg/L)	NA	130	160	34	11	16.7	NA	NA	19	—	—	—	—	—	—	—	—

Values are in μg/L. Values for the indicator parameters COD and phenolics are included for G-series wells for comparison purposes. No data on these parameters were available for C-series wells. (Source: IEPA, 1986). NA means sample not analyzed for this parameter. — indicates below detection level.

[1]Reading from November 1985; no value recorded for February 1986.

[2]Well destroyed since November 1985.

Table 10 Volatile organic chemical concentrations identified in samples collected in February 1986 from ISGS wells at the Wilsonville site

	Well number															
Compound	B1S[1]	B15S[1]	B1DS[2]	K4S	K3M	W1S	W1M	W1D[2]	W2D	W3D	V1S	V1M	V1D	V2S	V2M	V2D
Benzene	—	5.79	2630	—	—	—	—	—	—	—	96.5	—	45.9	—	—	—
Carbon tetrachloride	—	—	—	—	—	423	454	26,900	—	—	—	—	—	—	—	—
Chlorobenzene	—	—	—	—	—	—	—	—	—	—	—	157	—	55.1	—	—
Chloroform	—	—	—	—	—	459	218	5630	20.3	9.33	—	23.6	—	—	251	—
1,1-Dichloroethane	—	—	—	—	—	—	—	—	—	5.44	—	28.9	482	22.8	102	—
1,2-Dichloroethane	—	—	—	—	—	—	—	—	—	—	—	—	—	54.9	—	—
1,1-Dichloroethylene	—	—	—	—	—	—	—	—	—	—	—	19.5	—	19.8	—	—
Ethyl benzene	144	192	240,000	—	—	—	—	—	—	9.75	—	1580	13.3	—	—	—
Methylene chloride	—	5.25	—	57.8	68.5	—	—	—	—	—	—	27.7	—	58.8	591	—
Tetrachloroethylene	—	—	8390	—	—	—	12.2	1780	—	26.3	—	87.5	—	47.7	—	—
Toluene	7.74	4.59	7370	—	—	—	—	887	—	—	—	940	—	—	—	—
1,2-Trans-dichloroethylene	—	—	—	—	—	—	—	—	—	—	—	7.8	—	139	160	—
1,1,1-Trichloroethylene	—	—	—	—	—	—	—	—	—	—	—	539	—	366	573	—
Trichloroethylene	—	—	—	—	—	—	2.52	424	—	31.0	81.0	3430	247	6820	9970	15.9
Phenolics, total	NA[3]	31	NA[3]	—	—	NA[3]	7	730	7	10	—	7	—	—	—	8

Concentrations are given in μg/L. Positive values of the indicator parameter, phenolics, are included for comparison. (Source: Environmental Testing and Certifications, 1986). Note: Nest A, believed to be contaminated, was not sampled at this time. Nest V3 and V4, which are off the site, also were not analyzed. (Source: Environmental Testing and Certification, 1986)

[1]Wells monitor same zone. B1S is constructed of screw joint PVC; B15S is constructed of stainless steel. **S** designates shallow depth, M is for medium depth, and D is for deep wells. — indicates below detection level.

[2]Results are for water phase. Sample also had an oily phase. B1DS oily phase only had 15,700 μg/L ethylbenzene identified while the oily base phase of W1D was not analyzed for volatile organics. Oily phase of W1D produced a total phenolics value of 6500 μg/L.

[3]Sample not analyzed for this parameter. Oily phase of B1D5 was analyzed for phenolics and produced a value of 850 μg/L.

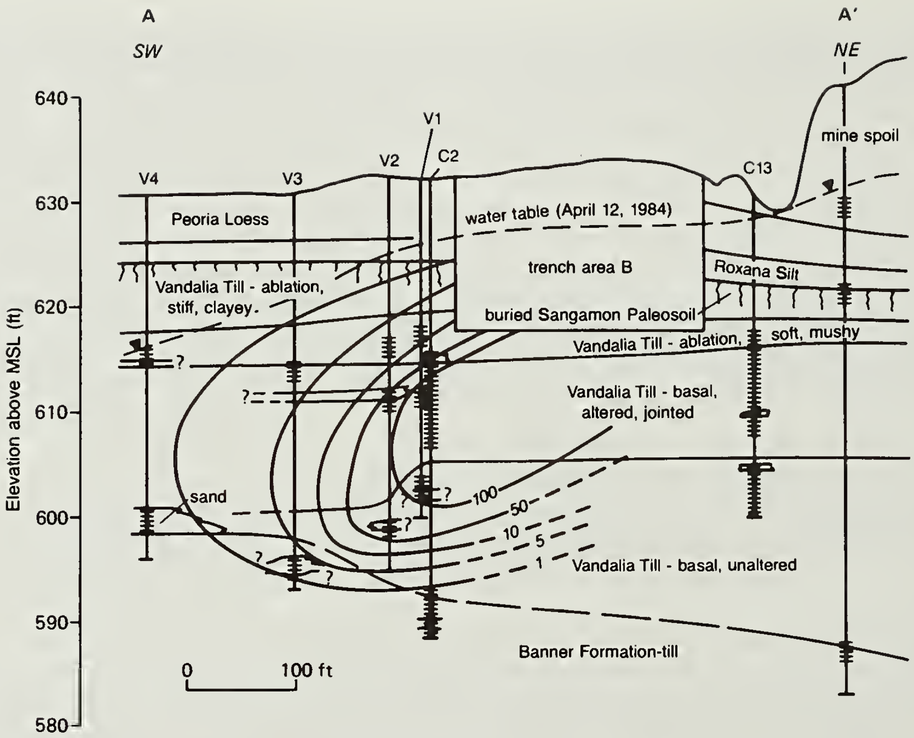

Figure 17 Trichloroethylene concentrations from profile V wells sampled in September 1984. Concentrations are in micrograms per liter.

Evaluation of Groundwater Monitoring Program

The monitoring scheme at Wilsonville has always been above minimum statute requirements. The original wells were generally less than 400 feet apart in areas downgradient of the proposed burial trench locations and generally had screen lengths less than 15 feet. The wells were constructed of PVC pipe joined with solvent cement, which is known to leach organic compounds that may interfere with water quality analyses. The operator paired wells around Trench Area A early in the monitoring program's history to detect both shallow and deep contamination. When contamination was discovered at G107, the operator responded promptly, installing a series of closely-spaced monitoring wells and a pumping well to remove the contaminated groundwater. Each well at the site has its own sampling device (fig. 16) to avoid the possibility of cross-contamination of samples from different wells.

The ISGS scientists noted three problems with the Wilsonville groundwater monitoring network. One apparent problem is that several wells had sand packs up to 20 feet long, spanning several geologic units. Long screens were used only for wells in which no sand lenses or other highly permeable zones were found, however. Those wells in which a highly permeable zone was found have shorter screens which span the highly permeable zone. It appears that the long screens were thought necessary to obtain an adequate sample for water quality analyses from what was believed to be very impermeable material.

The second problem: The trench boundaries were not well defined, so the distance from the edge of the trench to the monitoring wells is not accurately known. Without this information, accurate calculation of transit time is not possible. This could also be a problem if more monitoring wells are added to the system because one would want to be sure that a monitoring well was not placed in the trench. These inaccurate trench boundaries were discovered when the site was excavated.

The third problem: The vertical and horizontal extent of the contamination plume near G107 was never fully defined. Specifically, the operator did not install wells west of the property line. Chemical analyses of soil and water samples taken in 1984 from the ISGS V profile of wells indicate that small concentrations of several volatile organic compounds have migrated off-site (fig. 17). The extent of contamination southwest of Trench Area A also should be better defined to access the clean-up efforts.

The present groundwater monitoring system at the Wilsonville site appears adequate for detection monitoring. Well logs and construction records still exist, allowing ISGS to conclude that the wells are located in the most probable pathways of contaminant migration. Since there is no obvious uppermost aquifer, wells monitor the more permeable sand zones and fracture zones in the tills. In several cases, the system uses paired wells to monitor different depth intervals at the same location. These nested wells have a greater chance of intersecting contaminants by monitoring both shallow and deep groundwater flow without providing a pathway for contamination of clean zones. Most downgradient wells are very near trench boundaries. Many well samples now indicate contamination, which leads ISGS to conclude the groundwater monitoring plan has been able to detect significant levels of contaminant migration at this site.

The rate of contaminant movement originally could have been calculated more accurately if field measurements had been made of the hydraulic conductivity of the various geologic materials. Characterization of the geologic materials also would have been better if the well logs had been based on examination of continuous soil samples.

The monitoring program would be enhanced if more wells were added to fully define the vertical and horizontal extent of the contamination plume near G107 and G105. Deep wells were not placed in the immediate vicinity of G107 nor were any wells added outside the site's property to determine the extent of contamination. Additional wells are needed to better define the horizontal and vertical extent of contamination.

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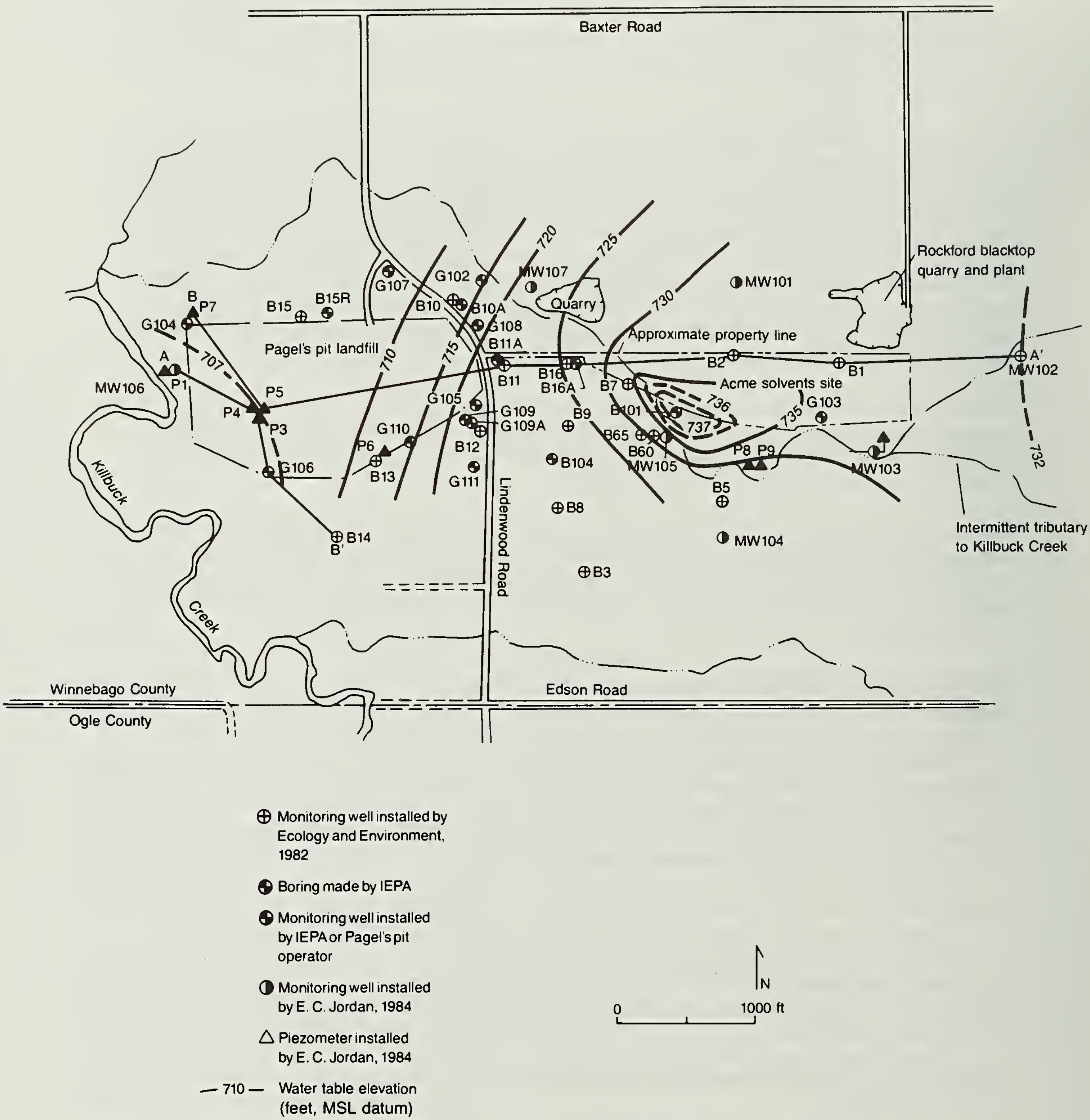

Figure 18 Map of Pagel's Landfill showing disposal area, well locations, contours of the top of the zone of saturation, and lines of cross section.

PAGEL'S LANDFILL

Site Description

Pagel's Landfill is a 60-acre waste disposal site operated by Winnebago Reclamation Service. It is located in southeastern Winnebago County, approximately 4 miles south of Rockford in the W 1/2 of Section 16, T27N, R10E. The site received an operating permit from the IEPA in 1972. This facility was used for disposal of municipal refuse, sewage sludge, inorganics, heavy metals, and minor amounts of organic liquids (phenols). Waste was disposed of in an asphalt-lined landfill equipped with a leachate collection system. Significant contamination of groundwater by organic priority pollutant compounds has been observed in monitoring wells on and around the site. Pagel's Landfill is located 1/4 mile west and downgradient of the Acme Solvents site, a former waste-solvent reclaiming site (fig. 18). It is difficult, therefore, to determine which site is the source of the groundwater contamination. ISGS personnel visited Pagel's Landfill in August 1985.

Geology and Hydrology

Pagel's Landfill is located in the Rock River Hill Country of the Central Lowland Physiographic Province of northern Illinois. The site is in an area of broad rolling uplands within a few hundred yards of Killbuck Creek. Surface water at the site drains westward to Killbuck Creek, which flows northwestward toward its confluence with the Rock River.

Unconsolidated material adjacent to and underlying portions of Pagel's Landfill consists of the Wasco Member of the Henry Formation, which is overlain by less than 5 feet of windblown Parkland Sand. The Wasco Member is characterized by ice-contact sand and gravel deposits, which vary laterally and vertically in grain size, sorting, bedding, and structure. These sand and gravel deposits may also contain thin, discontinuous lenses of till. The thickness of unconsolidated material at the site ranges from 10 to more than 60 feet. It thickens to the northwest into a northeast-southwest trending preglacial bedrock valley. Figures 19 and 20 show the possible relationships among the geologic units beneath the site.

Immediately beneath the unconsolidated material is dolomite of the Galena and Platteville Groups. The upper portion of the Galena Dolomite is weathered and highly jointed. The southeast portion of Pagel's Landfill is located directly on the Galena Dolomite, which was mined prior to the disposal of waste material. The elevation of the upper surface of the Galena Dolomite decreases sharply to the northwest into a preglacial bedrock valley.

The Wasco deposits and the Galena-Platteville dolomites are water-yielding and supply small to moderate amounts of groundwater for homes and farms near Pagel's Landfill. The regional potentiometric surface resides within the Galena Dolomite in the eastern portion of the site and within unconsolidated material in the western portion. In general, shallow groundwater flow is east to west (fig. 18). Variations in horizontal groundwater flow gradients, which range from approximately 0.0035 ft/ft to 0.018 ft/ft, are attributed to differences in permeability between geologic units (Warzyn, 1985). The shallow sand and gravel/dolomite aquifer system discharges to Killbuck Creek immediately west of the site. Piezometer pairs G104, P7 and P3, P4 (fig.19) are completed in the sand and gravel. Water levels in these pairs are similar, suggesting that deeper groundwater flow is primarily horizontal to slightly downward in the sand and gravel deposits beneath the valley of Killbuck Creek (E.C. Jordan, 1984a). Data from dolomite piezometer pairs B16, B16A and B13, P6 suggest that a slight downward, vertical flow gradient usually exists in the dolomite bedrock (Ecology and Environment, 1983; E.C. Jordan, 1984; Warzyn, 1985). Piezometer nests B6S, MW105 and B10, B10A completed in the bedrock, however, suggest that a slight upward groundwater flow gradient (0.0041 to 0.0052 and 0.0268 to 0.0355 ft/ft, respectively) exists in the dolomite (Warzyn, 1985).

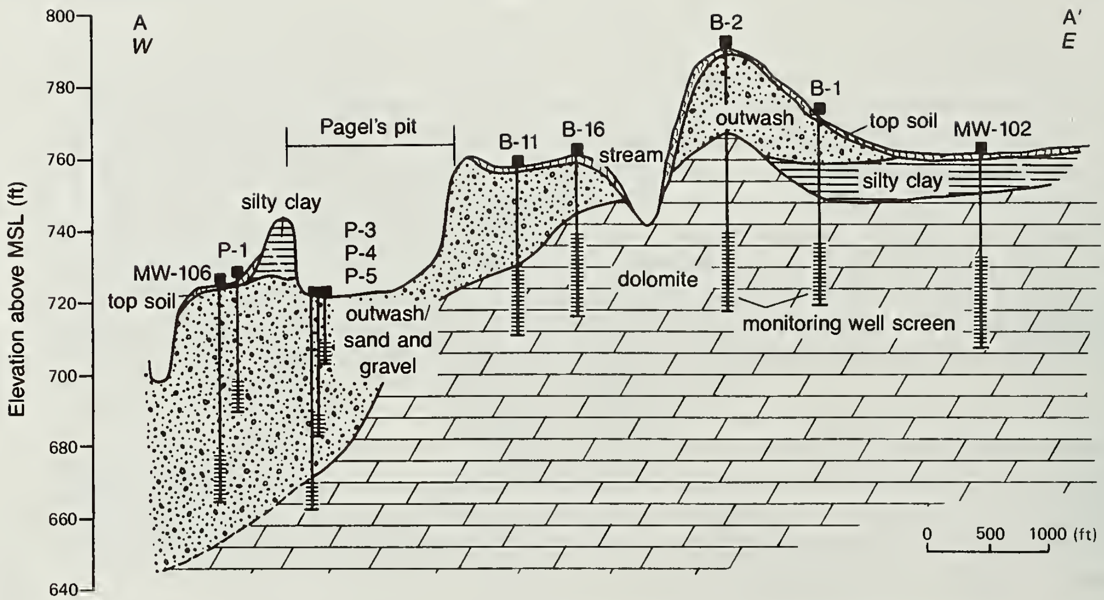

Figure 19 Pagel's Landfill cross-section A-A', west-east through the center of waste disposal area (adapted from E. C. Jordon, 1984).

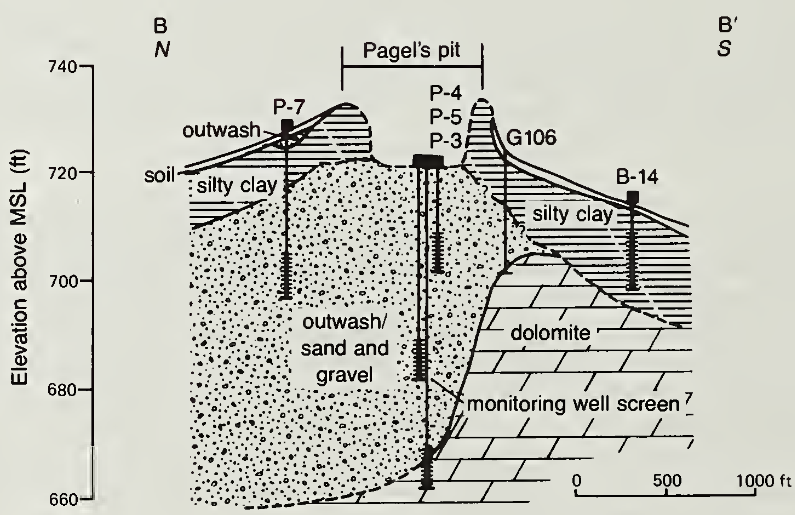

Figure 20 Pagel Landfill cross-section B-B', north-south through the center of the disposal area (adapted from E. C. Jordon, 1984).

Upward groundwater flow gradients also were reported between well P5, finished in the dolomite, and wells P3 and P4, finished in sand and gravel deposits (Warzyn, 1985). This variation in the vertical direction of groundwater flow within the bedrock may result from the fact that groundwater primarily flows through fractures in the dolomite. Because these fractures may not be interconnected or the well screens may be finished in fractures that are not connected, differences in measured groundwater elevations may result. Differences in the direction of vertical groundwater flow also may result from climatic (rainfall) variations. E. C. Jordan's 1984 data were collected in April and May, typically wet periods; Warzyn's 1984 and 1985 data were collected in December and January, generally dry periods.

Examination of the vertical (0.005 to 0.0044 ft/ft) and horizontal (0.0035 to 0.018 ft/ft) groundwater flow gradients within the sand and gravel deposits beneath Pagel's Landfill suggest that contaminant migration in the Wasco Member will be more extensive horizontally than vertically. With a hydrologic connection between the Wasco Member and the Galena-Platteville Dolomites, however, contaminants may enter these dolomites and migrate downward through fractures and solution features. Most local groundwater is from the shallow dolomite aquifer.

Three major aquifers underlie the Galena-Platteville Dolomites: the Ancell Group, the Ironton-Galesville Sandstones, and the Elmhurst-Mt. Simon Sandstones. Although the major sandstone aquifer of the Ancell Group, the St. Peter Sandstone, may be separated from the Galena-Platteville Groups by the Glenwood Formation, the potential exists for contaminants to migrate downward through the Galena-Platteville Groups to the Ancell Group because the aquitard does not prevent all flow. Whether or not contaminant migration has occurred or will occur in the future has not yet been determined due to the lack of deep monitoring wells in the vicinity of the site. Contaminants may also migrate to deep aquifers through the space between the wall of the hole and the casing in the wells, which are finished in the underlying Ironton-Galesville or Elmhurst-Mt. Simon Sandstones and open to the Ancell, Galena, and Platteville Groups. This is undocumented due to a lack of deep well construction data.

Groundwater Monitoring History

The 1972 operating permit for Pagel's Landfill required the installation of at least four monitoring wells. At least one of the four wells had to be installed before refuse was deposited in the landfill. The wells were installed in the four corners of the site without regard to hydrologic considerations. Two wells apparently were installed downgradient and two were placed upgradient of the disposal area. One of the upgradient wells supplied water to the site office. Information on the construction or depth of these monitoring wells is unavailable. In 1975, IEPA noted the lack of records and the need for two more monitoring wells, which were not constructed.

In 1981, IEPA installed four additional monitoring wells, replacing the original downgradient wells. Two wells (G102 and G105) were located upgradient and two wells (G104 and G106) were located downgradient of Pagel's Landfill. These early wells were constructed of PVC plastic and located in the corners of the site. Both downgradient wells monitored the shallow sand and gravel, while one upgradient well was finished in the dolomite. No information was found on the second upgradient well nor on the depths and drilling logs for the other three wells. IEPA required the wells to be monitored quarterly for chloride, iron, and TDS (total dissolved solids), but the procedures used for collecting groundwater samples were unreported.

The Winnebago County Department of Public Health noted volatile organic carbon in groundwater near Pagel's Landfill and Acme Solvents in April 1981. In response to contamination at the site, IEPA contracted Ecology and Environment, Inc. to install 17 monitoring wells (B1-5, B7-16, B6B, and B6D) near Pagel's Landfill and the Acme Solvents site in 1982. Constructed of galvanized steel, the wells range in depth from 15 to 100 feet. Twelve of the wells were

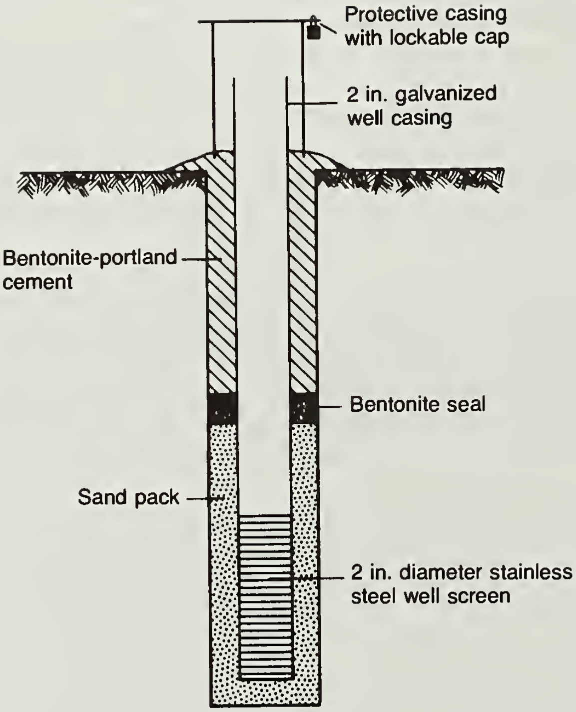

Figure 21 Typical construction of monitoring wells and piezometers at Pagel's Landfill.

finished in the shallow dolomite, three were finished in sand and gravel, and one was finished in till. Drilling was performed in accordance with current A.S.T.M. (American Society for Testing and Materials) B-1452-65 procedures. Figure 21 illustrates the typical construction used for the 17 wells. Ecology and Environment, Inc. tested the 17 new monitoring wells and six domestic supply wells in the area in 1982 for 30 organic priority pollutants and 14 inorganic pollutants. Sampling procedures were a modification of those outlined by the IEPA (IEPA, 1983). Eighteen wells (B1-5, B6B, B6D, B8, B10-13, B15, and five domestic wells) were contaminated with inorganics and volatile organics. The most common inorganic contaminant was barium, found in eight wells (B4, B12, B13, B5, and four domestic wells).

Following the discovery of groundwater contamination in these wells in 1982, E.C. Jordan, Inc., under contract to IEPA, added seven monitoring wells (MW101-107) in 1984 to better define the contaminant plume. Eight piezometers (P1-8) were installed at the same time to provide more data on the pattern of groundwater flow. The seven wells have stainless steel screens and galvanized steel casing. Seven wells are finished in the shallow dolomite at depths of 50 to 150 feet; one is finished in gravel at about 60 feet.

Forty-six groundwater samples were then collected from 26 monitoring wells, 14 domestic wells, and six piezometers in 1984. Substantial concentrations of organic compounds were found in groundwater samples from 26 wells, five of which are greater than 300 feet from the Pagel's Landfill boundary and near Acme Solvents (E. C. Jordan, 1984). The compounds included 12 volatile priority pollutants and one semi-volatile pollutant, bis (2-ethyl-hexyl) phthalate. The compound highest in concentration was trans-1,2,-dichloroethylene. Organic contaminants were concentrated in two regions: near well B4 on the Acme Solvent's site and near the southeast corner of Pagel's Landfill (fig. 22).

E. C. Jordan (1984a) identified three possible sources of groundwater contamination within the vicinity of Pagel's Landfill: Rockford Blacktop Construction Company, the Acme Solvents site, and Pagel's Landfill (fig. 22). Groundwater from the Acme Solvents site 1/4 mile to the east, which is known to be contaminated, flows directly beneath Pagel's Landfill (fig. 19). This increases the difficulty of detecting leachate migration and the origin of contaminants in downgradient wells at Pagel's Landfill. E.C. Jordan, Inc. (1984) concluded, however, that both Pagel's Landfill and Acme Solvents were possible sources of groundwater contamination. E.C. Jordan (1984) based its conclusions on the interpretation of a groundwater mound (suggesting landfill leakage) in the western portion of Pagel's Landfill and on chemical concentration profile data (of organic pollutants) along transections from Acme Solvents to Pagel's Landfill.

Warzyn Engineering, Inc., in 1984, installed 10 monitoring wells (G107 to G111, G109A, G10A, B15R, and B16A), constructed with stainless steel screens and galvanized steel well casing, in the vicinity of Pagel's Landfill (fig. 18). All the wells, except G107, were finished in bedrock at depths of 36 to 76 feet. Well G107 was finished in a sand and gravel deposit at a depth of 36 feet.

Warzyn Engineering analyzed groundwater samples from these 10 wells and 12 additional wells (G102, B8 to B16, and two domestic wells) in December 1984 and January 1985 for pH, specific conductance, alkalinity, chloride, arsenic, barium, cadmium, and 26 organic priority pollutants. Inorganic and phenol concentrations were elevated in wells north and west of Pagel's Landfill, and in well G110. Surface seeps of leachate were reported in the vicinity of well G110 and may account for the increase of inorganic concentration (Warzyn Engineering, Inc., 1985). Warzyn Engineering found concentrations of volatile organic compounds within the shallow aquifer system to be similar in areal extent to those determined by E. C. Jordan, Inc. in 1984 (fig. 22). Volatile organic compounds deeper in the groundwater, however, appear to be widely dispersed and in lower concentrations. Warzyn Engineering, Inc. (1985) concluded that two contaminant plumes, one dominated by a variety of organics and the second by inorganics and phenols, are present in the vicinity of Pagel's Landfill. In addition, Warzyn Engineering, Inc. (1985) concluded that Pagel's Landfill may be a source of inorganic and phenol groundwater contamination, but is not an apparent source of volatile organic contamination. Warzyn Engineering attributed the elevated concentrations of volatile organic compounds in the shallow groundwater system southeast of Pagel's Landfill to the movement of contaminants from the Acme Solvent site through the fractured dolomite.

Evaluation of Groundwater Monitoring Program

The initial monitoring program, in operation from 1972 to 1981, could not adequately monitor groundwater flow or contaminant migration at Pagel's Landfill. Four factors lead to this conclusion: 1) important technical information for monitoring wells installed in 1972 was unreported; 2) quarterly analysis of these wells did not include organic parameters, the major groundwater contaminants in the vicinity of Pagel's Landfill; 3) the distance between downgradient wells, approximately 1200 feet, was too great to adequately monitor contaminant migration; and 4) the Galena Dolomite was monitored by only one upgradient well.

The groundwater monitoring program was greatly improved in 1982, following reports of contamination in the vicinity of the site. Ecology and Environment, Inc. installed 17 new wells, required by the IEPA, near the Pagel's Landfill and Acme Solvents sites. In addition, groundwater sampling techniques were documented and analyses were upgraded to include 30 organic parameters. In 1984, E.C. Jordan, Inc. and Warzyn Engineering, Inc. installed 17 monitoring wells and 8 piezometers to reduce the distance between downgradient observation points to less than 600 feet and to monitor the dolomite and sand and gravel. These wells also were sampled and analyzed for organic priority pollutants and inorganic parameters using documented and accepted procedures. Two factors persist, however, that hamper groundwater monitoring

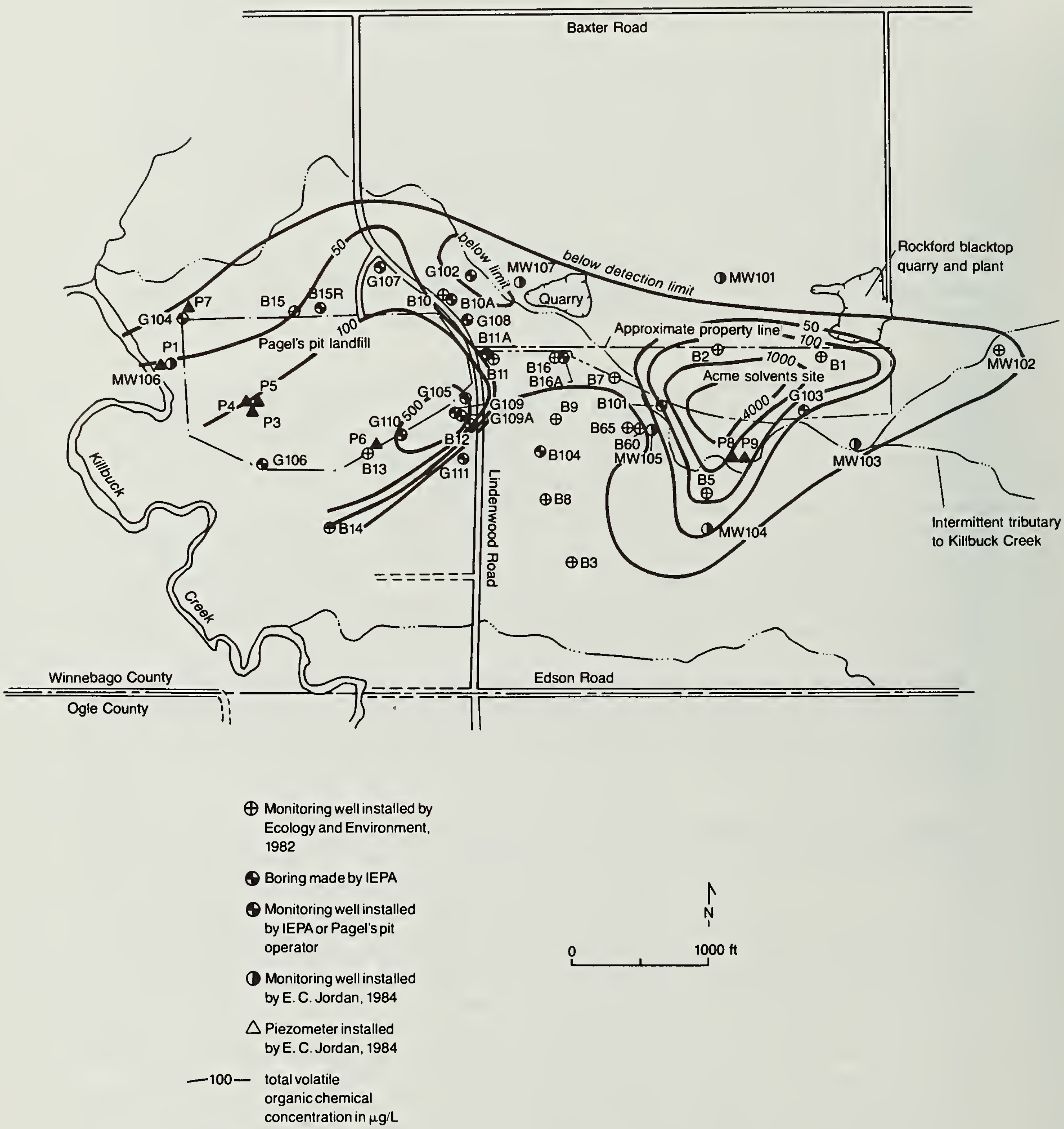

Figure 22 Map of Pagel's Landfill showing contours of total volatile organic chemical concentration.

programs in the vicinity of Pagel's Landfill: 1) the flow of contaminated groundwater from Acme Solvents to Pagel's Landfill makes it difficult to detect leachate migration that may originate from Pagel's Landfill, and 2) groundwater flow through the fractured Galena-Platteville dolomite is difficult to monitor, as shown by the discrepancies in calculated components of vertical groundwater flow and established origins of contaminants discussed earlier.

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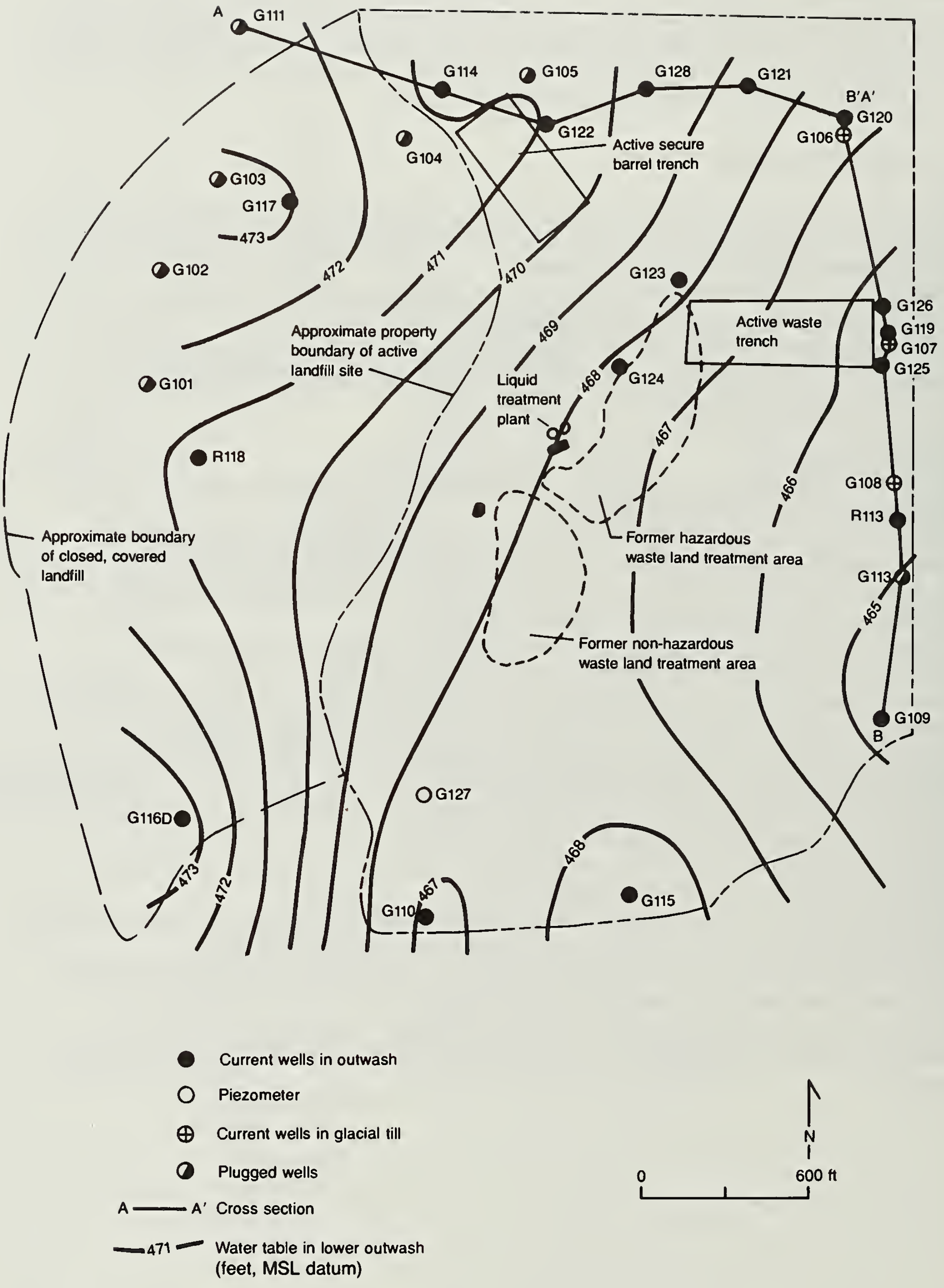


Figure 23 Map of Peoria disposal site showing wells, piezometer, cross-section lines, and water table in the outwash.

PEORIA DISPOSAL COMPANY

Site Description

The Peoria Disposal Company, Inc. landfill is immediately west of the City of Peoria, SW 1/4 Section 25 and W 1/2 Section 36, T9N, R7E, in Peoria County. The site began operation in 1968 with the approval of the Illinois Department of Public Health and received an operating permit from the IEPA in 1974 (IEPA, 1974). More than 4.5 million gallons of wastes had been disposed of at the site by 1980. The entire site covers 152 acres, 76 of which are currently operating under RCRA regulations (fig. 23). Most of the waste has been disposed of in a sanitary landfill, although landfarming has been used for some liquid wastes. Only the landfill is currently in operation. The site has accepted general refuse and special and hazardous wastes; most of the special and hazardous wastes are classified as iron/steel foundry wastes. The waste is considered hazardous because of high concentrations of heavy metals. General refuse is no longer accepted at the site. ISGS personnel visited the site in June 1985 to obtain further information on site geology and groundwater monitoring. According to company officials, contamination has not been detected by the monitoring system at the Peoria Disposal site.

Geology and Hydrology

The facility is located on a topographic high above Kickapoo Creek, on the west side of the Illinois River valley. The sequence of geologic materials consists of two types of glacial deposits (till and sand and gravel) overlying Pennsylvanian-age shale and sandstone. These deposits are shown on cross-sections A-A' and B-B' in figures 24 and 25.

The upper glacial sequence belongs to the Glasford Formation. It contains sandy, silty clay till, lenses of silt, and sand and gravel. The sequence ranges from 75 to 150 feet in thickness beneath the disposal area, and averages 100 feet. The upper 25 to 35 feet of the sequence are weathered, while the lower portion shows little evidence of alteration.

Beneath the till lies an older sequence of outwash which is predominantly brown, coarse-grained sand (Peoria Disposal Company, 1986), sequence 2. The sand increases in thickness from 20 to 30 feet in the west to a maximum thickness of 91 feet at the east property line (M. Rapp Associates, 1983). Beneath the site, the upper portion of sequence 2 is unsaturated. The saturated thickness averages 23 feet on the west side of the site and 34 feet on the east side. Groundwater flow in this sand beneath the site is to the southeast. The water table in the sand is shown on the site map (fig. 23) and both cross sections (figs. 24 and 25). Sequence 2 appears to be adjacent to the west edge of and hydraulically connected to the Sankoty Sand, a major aquifer in west central Illinois. In the Illinois River valley to the east, the thickness of the Sankoty Sand varies from 50 to 150 feet thick, and may reach nearly 300 feet under the uplands. Characterization of the thickness and extent of the sand lenses in sequence is sometimes difficult due to inconsistent boring logs. Figure 25 shows a thick sand lens in the northeast corner of the site. Logs for wells G119 and G120 indicate the presence of 20 feet of sand. The logs for wells G107, G125, and G126, located on both sides of G119, however, show only a few, thin sand seams. The log for G119 also shows the top of sequence 2 at approximately 20 feet higher in elevation than in the surrounding wells. To resolve the discrepancy between the logs of these two wells, the position of G119 is adjusted in figure 25.

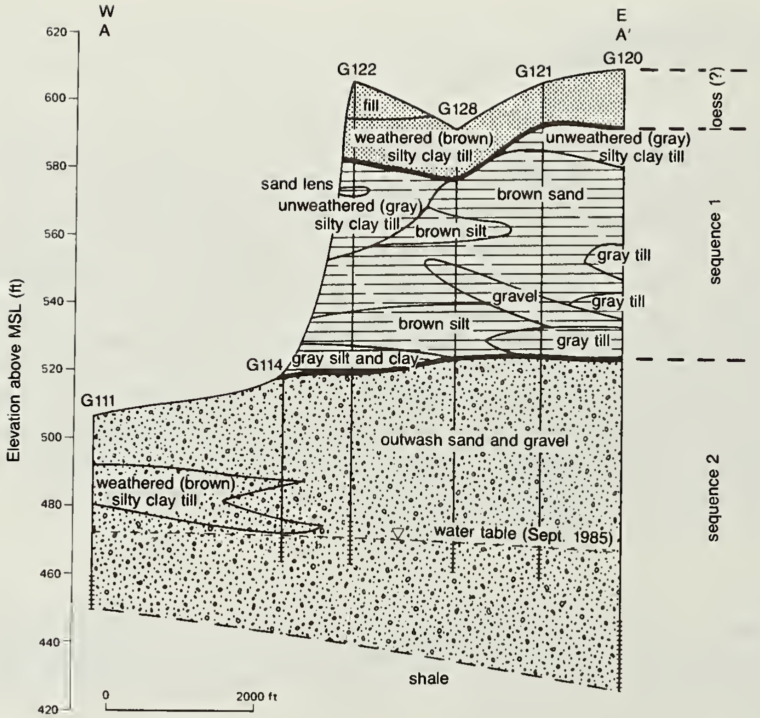
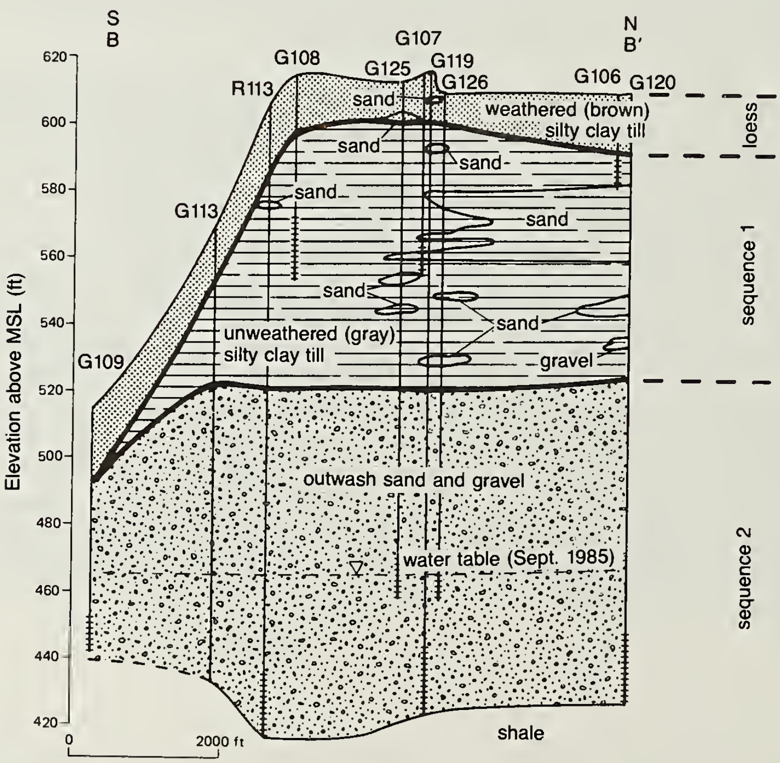


Figure 24 Cross-section A-A' along north side of Peoria Disposal Company site.



Figures 25 Cross-section B-B' along east side of Peorial Disposal Company site.

Groundwater Monitoring History

When IEPA issued the first operating permit to Peoria Disposal in 1974, groundwater was monitored using only three wells (G101 to G103 at depths of 21.8 to 56.6 feet), constructed of one-inch PVC pipe with solvent-cemented joints. Wells on the west side of the site were finished in the till (fig. 23). These wells originally were to monitor for iron, chloride, and total dissolved-solids, but because they were usually dry, consistent sampling was impossible. These early wells also were upgradient of most of the disposal activity. Through the years the monitoring system has been improved. Monitoring now is concentrated in the sand (sequence 2) designated the uppermost aquifer for groundwater monitoring purposes.

By 1983, 16 wells (G101-116D) were included in the groundwater monitoring program (Peoria Disposal Company, 1983; IEPA, 1983a & b). Six of the wells (G101-105 and G112) were later plugged because they did not yield water and another (G111) was plugged because its top had been destroyed (Peoria Disposal Company, 1985). The trend through the years has been to place more wells on the east side of the site and in the lower sand sequence, to use better well construction materials, and to measure more chemical parameters. This trend is evident in the well construction details shown in figure 26. The annular space in the boreholes surrounding wells G106-112 and G113 is filled with auger cuttings placed directly over pea gravel. The auger cuttings could introduce contaminants into the well if the cuttings were contaminated. The cuttings also may not seal the monitored zone from water seepage originating from higher zones. Wells G114-116D have only one foot of silty clay backfill in the annular space, which is covered by bentonite pellets and a silty clay-bentonite grout. This type of backfill should isolate the monitored zone and decrease the problem of using possibly contaminated auger cuttings. Wells G117-128 and R118 have no cuttings as backfill. They were sealed with cement-bentonite grout from the pea gravel to the surface, usually with a plug of bentonite pellets between the grout and the gravel. This well construction method is preferred to methods used on the earlier wells.

Soil-water samplers (suction lysimeters) were installed beneath the land treatment area to monitor water quality in the underlying till. According to the site manager, contamination was never found in the soil-water samplers, which were removed when the land application area was closed and seeded. Information regarding the numbers, locations, or construction details of these lysimeters is not available.

By spring 1985, the groundwater monitoring program consisted of 13 wells (G106-110, G113-120, G116D and R118), three of which (G106-109) are pre-RCRA wells finished in shallow, saturated sand lenses within the till (IEPA, 1984). The 13 wells are constructed of PVC solvent-cement joints. The ten wells installed since RCRA's inception are constructed of PVC casing with screw-thread joints. They monitor sequence 2 and have 5- to 25-foot gravel packs. Nine of the ten wells monitor deeper parts of sequence 2 and most extend to bedrock. The exception is G114, the designated background well, which has a 5-foot screen finished at the top of sequence 2 (Whitney, 1981-1985). At least two IEPA inspection memorandums (IEPA, 1983b and 1984) incorrectly state that the ten wells were screened in the upper portion of the sequence 2. According to the site manager, IEPA instructed the company to place the well screens at the bottom of sequence 2 (Peoria Disposal Company, 1986).

The monitoring wells are located around the perimeter of the site; four are upgradient wells. Each well was monitored for one year in the early 1980s to establish initial water quality. Since the initial water quality has been established, the shallow (pre-RCRA) wells are monitored quarterly for alkalinity, boron, chloride, pH, residue on evaporation (ROE), specific conductance, sulfate, toluene, total organic carbon (TOC), total organic halogen (TOX), and xylene. The new wells finished in sequence 2 were monitored quarterly for 43 parameters, beginning in 1984, to establish initial water quality. Some of the parameters tested included heavy metals, organic com-

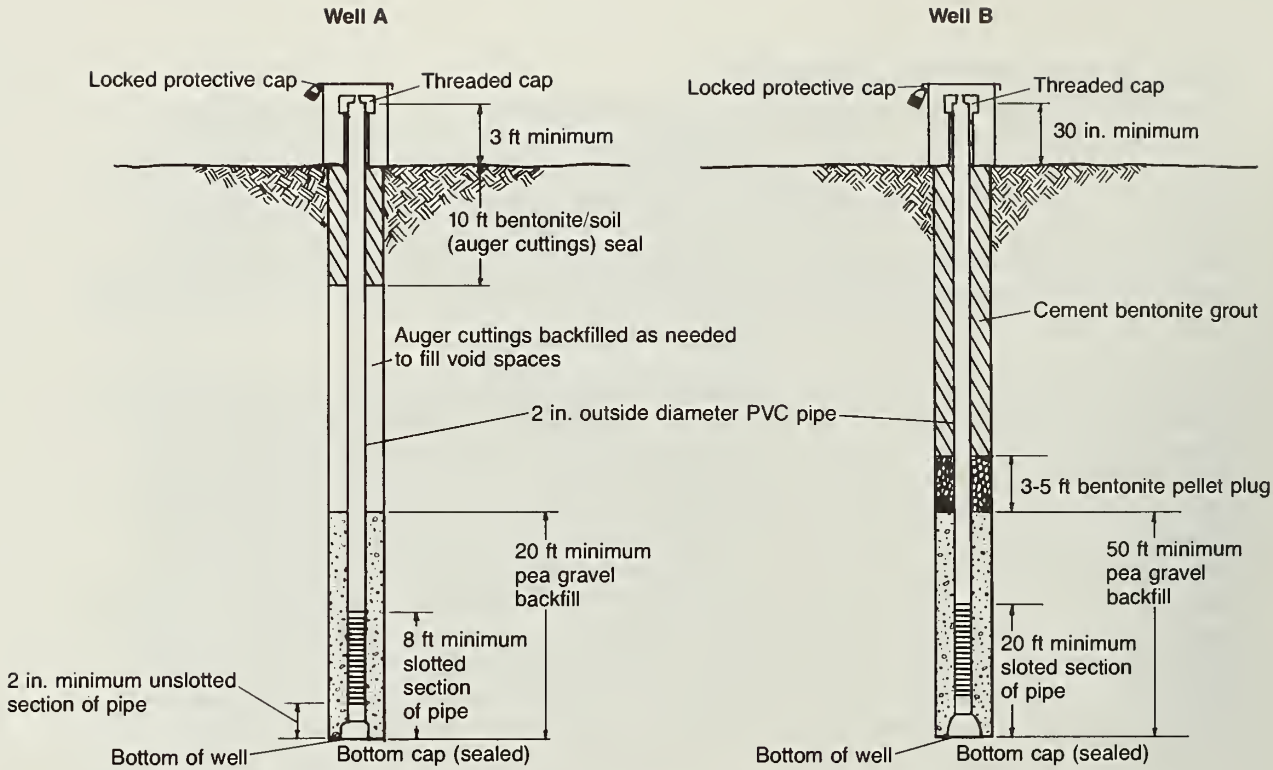


Figure 26 Typical construction of monitoring wells at Peoria Disposal Company. Well A represents the old wells (G100-113) finished in sand lenses within the till. Well B typifies the newer wells (G118-120) finished in sequence 2 (from Whitney, 1980-1985).

pounds, and gross alpha beta radioactivity. These deep wells now are analyzed quarterly for pH, specific conductance, TOC, TOX, xylene, toluene, chloride, iron, manganese, phenols, sodium, and sulfate. According to the company, the wells are sampled and analyzed according to IEPA guidelines.

In April 1985, the operator met with the IEPA and agreed to upgrade its monitoring program to include seven or eight new stainless steel monitoring wells (fig. 23; IEPA, 1985). The facility installed seven monitoring wells and one piezometer the following summer. Since no saturated sand lenses were encountered in the till, three wells, approximately equally spaced along the north boundary, were installed in sequence 2. Two of the remaining four wells were placed upgradient and two were placed downgradient of the new disposal trench. These four wells also monitor the top of the saturated portion of sequence 2. To eliminate any possibility that PVC well casing may leach trace amounts organic compounds into water samples, IEPA required the new wells to be constructed of galvanized steel with stainless steel screens and a short length of stainless steel casing above the screen. Company files indicate that these wells were constructed in a manner similar to wells G117 and G120. In addition, one piezometer (G127) was added for water-level measurements on the south side of the site.

The Geological Survey staff plotted the concentrations of pH, ROE, chloride, iron, TOC, TOX, selenium, and nitrate from all IEPA computer files of water quality data versus time through summer 1985. The data revealed no obvious changes in water quality. ISGS scientists then mapped concentrations of chloride, iron, specific conductance, ROE, TOC and TOX in the most recent, complete set of water samples. Phenols were not mapped because their concentrations were

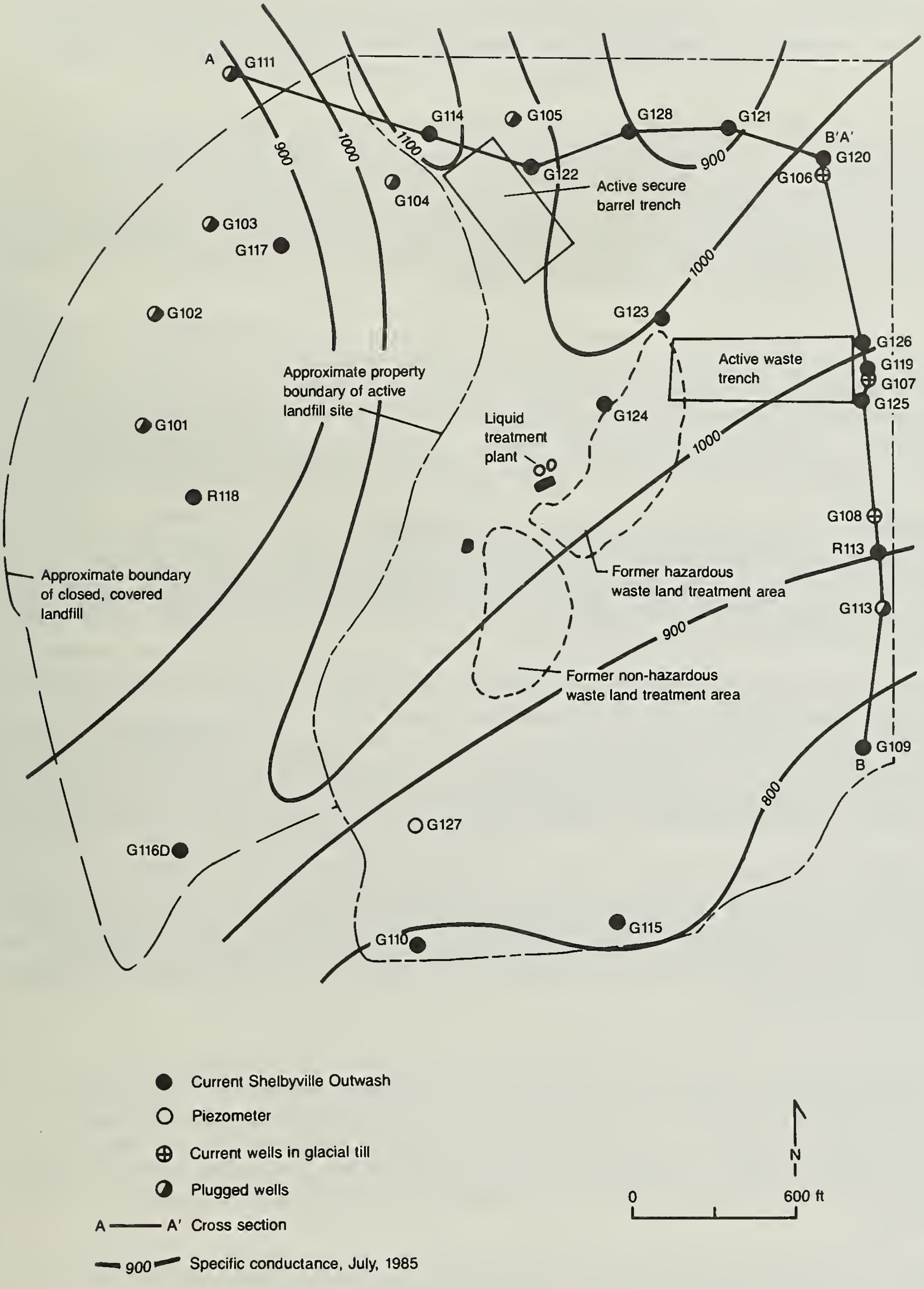


Figure 27 Map of Peoria Disposal Company site showing specific conductance values measured in July 1985.

entirely dependent on sampling episodes. All samples collected on the same date had the same phenol concentration. Preparation of concentration maps also was difficult since concentration values were reported for incorrectly identified wells. Although the data are probably for wells on the site, their locations could not be assigned without the correct well numbers.

Figure 27 is a map of specific conductance in the sequence 2 in July 1985. These values are lower than values for previous sampling periods and are part of a trend toward lower numbers. Values of specific conductance in the shallow sand lenses are all lower than those in the sequence 2. This is also true for most other constituents. The trend in specific conductance seen in the sequence 2 is similar to patterns mapped for chloride, TOX, and ROE. The isopleths in figure 27 show the highest values along a northeast-southwest line across the site. The lowest values are on the southeast and west sides of the site.

G114, the designated background well, had the highest value of specific conductance. G114 also had elevated values of TOC, TOX, and ROE. The cause of these elevated values is not readily apparent although a reported waste disposal operation existed north of the site in the 1950s. The high values of TOC, TOX, and ROE suggests that G114 should not be used as the sole background well. G117, which had among the lowest values for all parameters tested and appears upgradient on the piezometric surface map (fig.23), should be the designated background well.

Evaluation of Groundwater Monitoring System

The original groundwater monitoring program was inadequate. Since the stratigraphy and groundwater flow system were not understood, all the wells were located upgradient. In addition, the wells were finished in the till or sand lenses in the till, and none monitored the major aquifer beneath the site, the outwash (sequence 2).

Sampling and descriptions of geologic materials in the test boring program were not adequate. The boring logs should have been more descriptive of sand lenses. Samples taken during the boring operation may have been too widely spaced, which makes determination of the geology and the proper depth for monitoring wells difficult. A case in point is shown in figure 25 between wells G107 and G119, where an extensive sand lens is shown to begin abruptly. This illustrates that complex stratigraphy cannot be simplified and still be expected to be useful to site studies.

Early records of the Peoria Diposal Company site are poor. ISGS scientists could not find any definite logs of wells G101 to G105 nor any records on lysimeter installation. While more recent maps show well locations, several base maps have been used and well locations do not match precisely on the various maps. All wells are correctly placed on a master boring location map, however. Wells G107 to G109 have solvent-cemented joints, which may interfere with analyses for organic contaminants.

The monitoring system has improved significantly through time. The horizontal spacing of downgradient wells, now less than 800 feet, appears marginally adequate. Many of the wells, however, are screened at the bottom of the aquifer, the least likely spot for them to intersect some contaminants. This deep screening was done as prescribed by the IEPA in 1984 (Peoria Disposal Company, 1986). The addition of the four new wells in the immediate vicinity of the new active waste trench has greatly improve the program, as have the new wells along the north edge of the site.

Although the sequence 2 (improperly called either "Sankoty Sand" or "Shelbyville Outwash" in the records) is designated as the uppermost aquifer for monitoring purposes, the sand lenses in the till also should be monitored as a first warning of contaminant movement from the site. Although not required by federal regulations, shallow monitoring for the site is required by the state. The major emphasis, however, should remain on monitoring sequence 2 since values of most

parameters are higher in the outwash than in the shallow sand lenses and because sequence 2 is a potential water source. The higher parameters values in sequence 2 may be a natural phenomena or mean that the migration is mainly vertical and misses the sand lenses.

The list of parameters used for analysis appears adequate. No contamination has been reported at the site. Background water quality, however, has only recently been established for the deep outwash (sequence 2) wells and is in progress for the wells installed in 1985. Although the records do not show deterioration in water quality at individual wells through time, there is an area of higher concentration running through the site. Changes in water quality at the Peoria Disposal site should be monitored closed to ascertain whether the higher indicator concentrations are the result of natural water quality, previous activities near the site, or current disposal activities.

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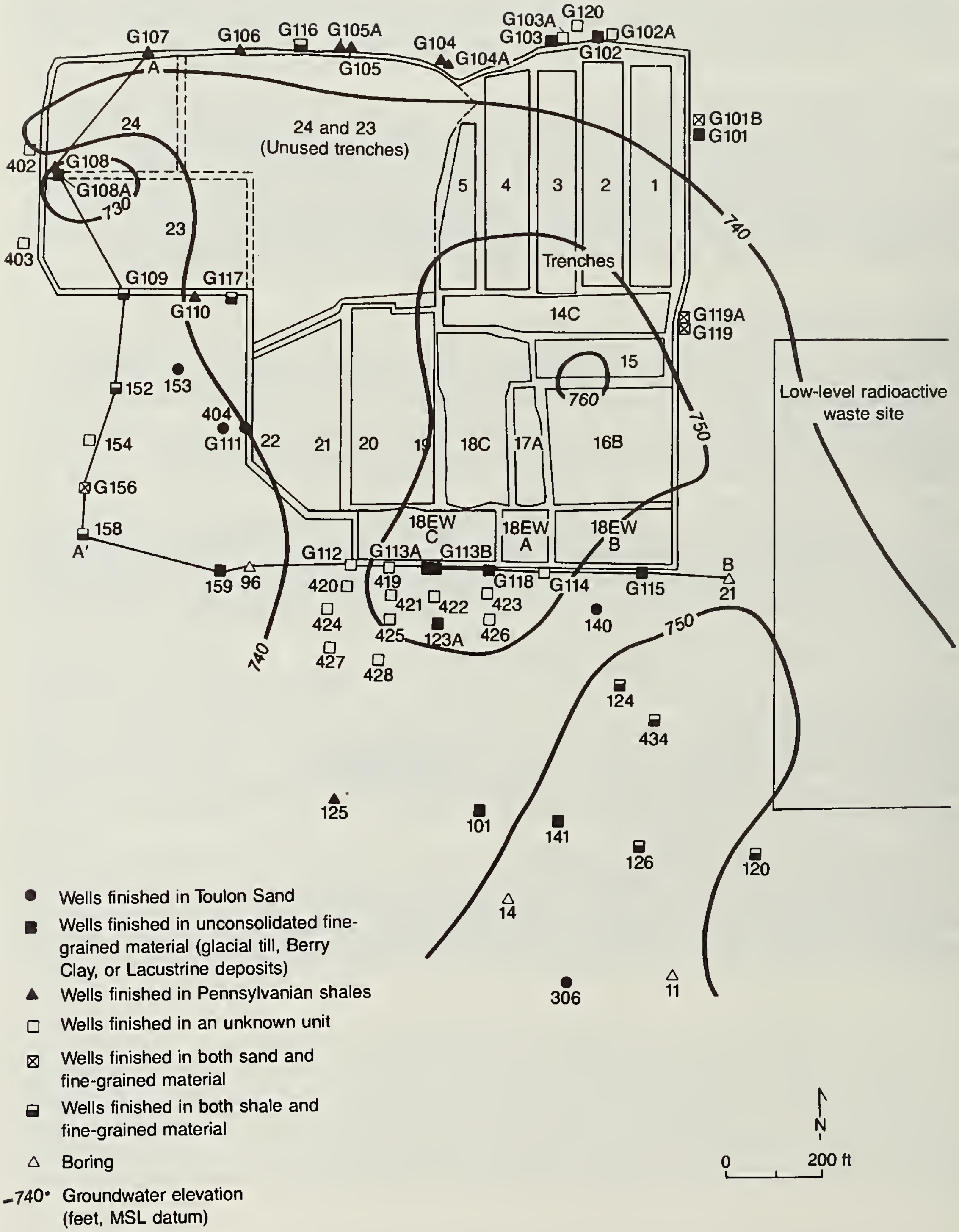

Figure 28 Map of the Hazardous Waste Management Facility showing disposal areas, well locations, contours of the top of the zone of saturation, and lines of cross section (adapted from U.S. Ecology, 1984).

U.S. Ecology No. 2

Site Description

The U.S. Ecology, Inc. (formerly Nuclear Engineering Company, Inc.) No. 2 Hazardous Waste Management Facility (HWMF) is located in Section 26, T16N, R6E, Bureau County, approximately 3 miles west of Sheffield. The facility is immediately adjacent to an older hazardous waste disposal site and a low-level radioactive waste disposal site (fig. 28), both of which were operated by U.S. Ecology, Inc. The 40-acre chemical waste site received an operating permit from the IEPA in 1974. It ceased operations in January 1983; official closure is pending. During operation, the U.S. Ecology No. 2 disposed of approximately 4.2 million cubic feet of waste of in shallow trenches excavated in 16 acres of the 40-acre site (fig. 28). Disposed wastes included solvents, paint sludges, neutral organics, organic acids, cyanides, pesticides, reducers, oxidizers, acids, and bases. All of the waste was containerized, except building rubble and specially permitted rubble. Rainwater which accumulated in the disposal trenches during excavation and disposal operations was pumped to a roofed surface impoundment for evaporation. The surface impoundment was filled and covered prior to site closure. Monitoring wells at the site have detected up to 14 pollutants; eight are organic priority pollutants. ISGS personnel have visited the site on several occasions.

Geology and Hydrology

The U.S. Ecology HWMF is situated on a drainage divide that separates King Creek to the west and Lawson Creek to the east. The two creeks flow northward and discharge into the Illinois Hennepin Canal. While the region has been extensively strip mined for coal, the site has not been mined. Small lakes, a result of strip mine activity, are common west and northwest of the disposal site.

Overlying the Pennsylvanian-age bedrock is approximately 50 feet or more of unconsolidated glacial deposits. From youngest to oldest, these deposits include recent alluvium, Peoria Loess, Roxana Silt, Berry Clay, Radnor Till, Toulon Sand, and Hulick Till. These units are briefly described below. A detailed description of each unit can be found in Willman and others, 1975.

The alluvial deposits, consisting of interbedded sand, silt and clay, occur predominantly in low-lying areas adjacent to streams and/or rivers. The Peoria Loess consists of weathered, eolian silt with minor amounts of sand and clay. It generally thickens on uplands and thins toward valleys. The Roxana Silt is composed of weathered silt which may contain some sand and gravel at its base. The Berry Clay, a member of the Glasford Formation, is a 1- to 5-foot thick deposit of clay and silty clay containing a few small pebbles. The Radnor Till Member of the Glasford Formation overlies the Toulon Sand and is a silty clay which may locally contain small pebbles and sand lenses. The Radnor Till has been identified in several borings adjoining to the HWMF. This till member, however, has not been identified in any borings within the HWMF and may, in part, have been modified into the Sangamon Soil (U.S. Ecology, 1984a). The Toulon Sand Member of the Glasford Formation is composed of a pebbly to silty sand. This unit is interpreted as a glacial outwash deposit. The Hulick Till Member of the Glasford Formation unconformably overlies Pennsylvanian shales and is highly variable in composition. In general, the till is composed of clayey silt to sandy, silty clay which may contain coal, shale, and pebbles of various lithology.

The cross sections in figures 29 and 30 show the possible site-specific geologic relationships among these units. Local variations in the extent of and relationships among these geologic units are likely due to the complex geology of the site and lack of geologic detail in portions of the monitoring well and test boring data. The large number of monitoring wells and test borings (132) at the site and the use of geophysical surveys south of Trench 18EW, however, have supplied sufficient data to determine the general relationships among the geologic units.

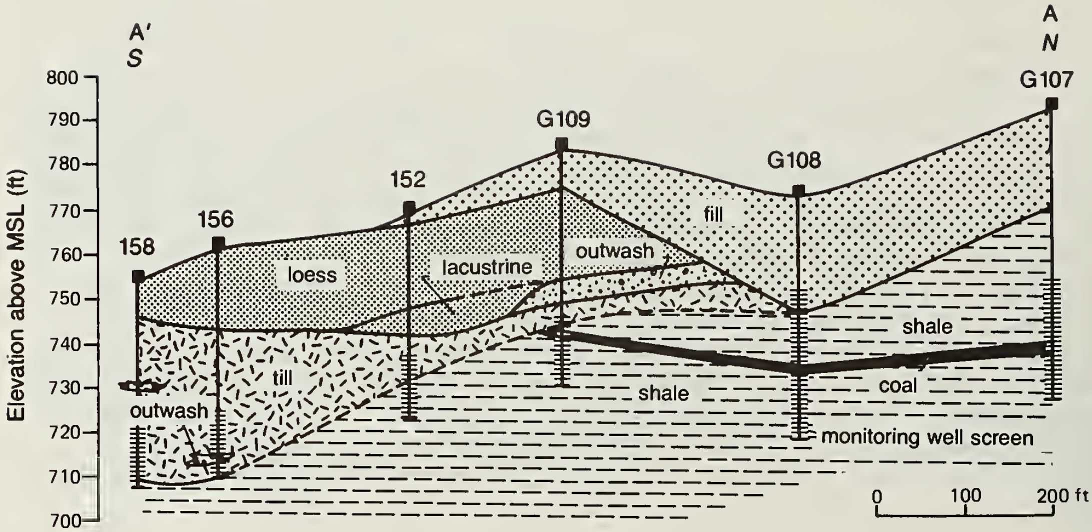

Figure 29 U.S. Ecology No. 2 Hazardous Waste Management Facility cross-section A'-A, south-north through western portion of disposal trenches 23 and 24.

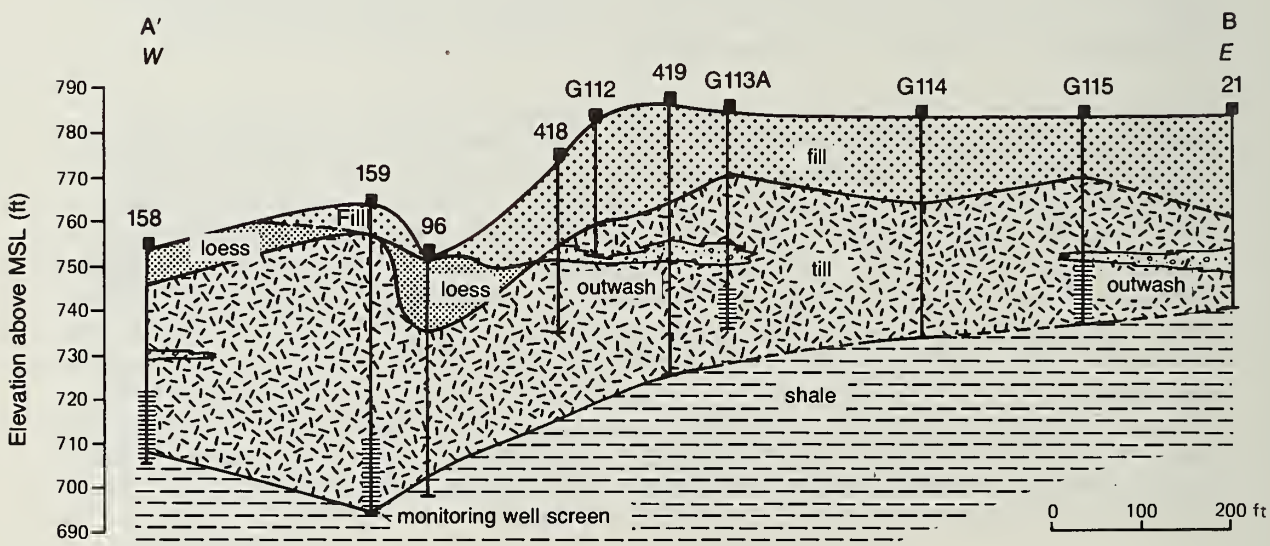

Figure 30 U.S. Ecology No. 2 Hazardous Waste Management Facility cross-section A'-B, west-east along the southern boundary of disposal trenches.

Hydraulic conductivity values of the glacial deposits, determined by field (slug) tests of 14 wells, range from 1.6 x 10^{-6}cm/s to 2.05 x 10^{-3} cm/s (Thorton, 1984). The average hydraulic conductivity of the Toulon Sand, derived by slug tests, pumping test, and inflow tests, ranged from 10^{-5} cm/s to 10^{-3} cm/s (U. S. Ecology, 1984). No recent hydraulic conductivity calculations for individual glacial units have been performed. The initial permit proposal stated that the loess deposits have vertical and horizontal conductivities of 10^{-5} cm/s and 10^{-4} cm/s, respectively. Till units and the Berry Clay Member have an approximate hydraulic conductivity of 10^{-8} cm/s. This hydraulic conductivity data suggests that groundwater and leachate released from waste trenches will migrate most rapidly through the Toulon Sand, which has the highest average hydraulic conductivity. Although the Toulon Sand is interpreted to occur beneath Trenches 14C, 15, 16, 17, 18EW, 19, and 20 (fig. 28), engineering reports by the site's consultants indicate that the trenches were excavated in material other than the Toulon Sand, except for a sand pocket located at the bottom of the western end of the trench 18EW. U.S. Ecology reports the sand pocket was removed and replaced with a 10-foot thick clay barrier (U.S. Ecology, 1986). Flow from disposal trenches also will be retarded by the presence of compacted earthen barriers which line waste trenches.

The glacial deposits are underlain with approximately 300 feet of Pennsylvanian-age shales and mudstones, with occasional sandstones, siltstones, and coal beds. These bedrock units typically dip to the south-southeast. The slope of the bedrock surface extends from a bedrock high in the north central portion of the waste site (below the center of trench 24 in fig. 28) to the southern boundary of the facility. Total relief of the bedrock surface beneath the site is approximately 60 to 70 feet.

In general, the Pennsylvanian units do not yield water; however, significant groundwater flow may occur locally through fractures in the shales and mudstones and through coal deposits. Beneath the low-permeability, Pennsylvanian-age bedrock units are five major bedrock aquifers: the Hunton Limestone Megagroup, the Ancell Group, the Prairie Du Chien Group, the Ironton-Galesville Sandstone, and the Elmhurst-Mt. Simon Sandstone.

Potentiometric surface maps for individual geologic units at the HWMF could not be constructed because 1) the site geology is complex, 2) several wells are finished in more than one geologic unit and have screens more than 10 feet long, and 3) the geologic unit in which several wells are finished is unknown. A water table elevation map was constructed instead (fig. 28), using water level data from wells finished in various units and from wells finished in more than one unit. Hence, the map illustrates only general trends in shallow groundwater flow. The map shows that the HWMF is located on a groundwater high that roughly corresponds to the surface topography. Shallow groundwater beneath the facility probably flows radially away from this groundwater high and predominantly discharges into strip mine lakes adjacent to the site. The downward migration of groundwater beneath the site is retarded by low-permeability, Pennsylvanian units; in particular, the underclay beneath the shallow No. 7 Coal. Contaminant migration through the Pennsylvanian-age units to the five major bedrock aquifers beneath the facility is unlikely, but undocumented, since data on deep groundwater flow for this area are nonexistent.

Most of the trenches were reportedly excavated in unsaturated deposits. Some anomalously high groundwater levels, however, have been reported in trench construction records and in some borings and wells (for example, G101B; U.S. Ecology, 1984a) within the till units beneath the site. Thornton (1984) suggested that the anomalous water levels indicated the presence of "perched water tables" in this unit. In addition, leachate accumulated in waste trenches, partially because of the difference in permeability between the trench fill and the trench liner.

Groundwater Monitoring History

In 1973, six borings were drilled to characterize the proposed disposal site's geology and hydrogeology for the operating permit application. The sands encountered in the borings were interpreted to be thin and discontinuous; however, the interpretation required revision after addition-

Table 11 Summary of chemical parameters analyzed in 1974 for monitoring wells at the U. S. Ecology No. 2 HWMF

January	*April*	*July*	*October*
Alkalinity	Calcium	Hardness	pH
Magnesium	Chloride	Potassium	Sulfate
Ammonia	COD*	ROE**	Sodium
Boron	Mercury	Iron	Chromium
Zinc	Manganese	Lead	Copper
Cyanide	Beryllium	Arsenic	Phenols

* Chemical oxygen demand
** Residue on evaporation

Table 12 Wells installed after 1980 were analyzed quarterly for the following parameters to establish water quality (U. S. Ecology, 1984b)

Alkalinity	Copper	Magnesium	Selenium
Ammonia	Endrin	Manganese	Silver
Arsenic	Fecal coliform	Mercury	Sodium
Barium	Fluoride	Methoxychlor	Specific conductance
Boron	Gross Alpha	Nitrate-nitrite	Sulfate
Cadmium	Gross beta	pH	Total organic carbon (TOC)
Calcium	Hardness	Phenols	Total organic halogen (TOX)
COD	Iron	Potassium	Toxaphene
Chloride	Lead	Radium	2,4,-D
Chromium	Lindane	ROE	Zinc

al information became available. When IEPA issued the operating permit a year later, Nuclear Engineering Company installed five wells (G196-199 and MW2) and one surface-water observation point. IEPA specified the locations for three of the wells. The five wells were required to be monitored quarterly for TDS, chloride, iron, and pH. An additional 21 chemical parameters (mainly metals, anions, and phenols) were required to be analyzed annually on a rotating basis, five or six each quarter (table 13; U.S. Ecology, 1984a). The procedures used for sample collection were not reported.

In 1976, Nuclear Engineering Company installed 11 monitoring wells (101-104, 120, 124-128, 141 and 142) south to southeast of the HWMF as part of the monitoring program for the low-level radioactive waste site. These wells and MW3, also added in 1976, may be used to monitor groundwater from the HWMF. Two wells (90 and 96) were added west of the HWMF in 1977 and three (G101-103) were added north of the site in 1978. The list of parameters analyzed in samples from these monitoring wells was not changed in subsequent permit letters.

Sixteen wells (G104-119) were added in 1980. They were to be analyzed quarterly for 40 parameters, the original 25 and others required by RCRA for establishing background water quality (table 11). In addition, U.S. Ecology began using sampling and testing procedures stipulated by the IEPA and described in the U.S. Ecology facility operating procedures.

In March 1982, total organic carbon and total organic halogen were detected in two wells (G112 and G113) immediately south of Trench 18EWC. U.S. Ecology placed 13 wells (G113A, G113B, and 418-428) south of Trench 18EWC in response to this on-site migration and expanded the list of monitoring parameters to include organic priority pollutants for the contaminated wells. The wells are currently monitored monthly for five indicator parameters: total organic carbon (TOC), total organic halogen (TOX), chemical oxygen demand (COD), pH, and specific conductance (U.S. Ecology, 1984a).

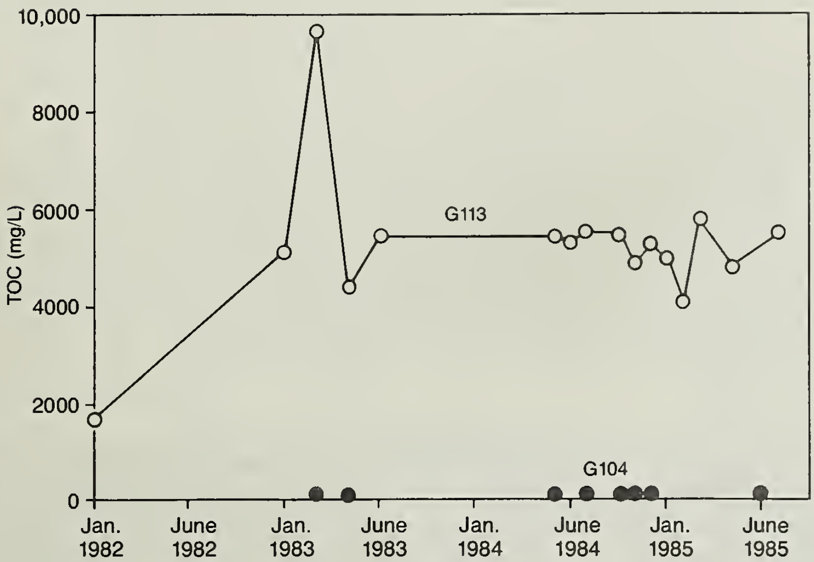

Figure 31 Total organic carbon (TOC) concentration of U.S. Ecology monitoring wells G113 and G104. Measurements were made between January 1982 and June 1985.

Concentrations of these five indicator parameters within the limits of the plume are variable. The TOC concentration near well G113 exemplifies this variability (fig. 31). U.S. Ecology suggests this variability in contaminant concentrations is due to dilution, diffusion, sorption, and analytical variability at low contaminant concentrations (U. S. Ecology, 1984a). TOX data from monitoring wells G113A, G113B, and 418 to 428 (fig. 32) indicate that contaminants were present in approximately 1.5 acres of U.S. Ecology property in 1984. The contaminated area covered a saturated thickness ranging from 5 to 35 feet (U.S. Ecology, 1984a). Most of the contaminants were in the Toulon Sand, although some also occurred within finer-grained material. The rate of contaminant migration, calculated from TOC data collected from monitoring wells, is estimated to be 96 feet per year (Thornton, 1984). The contaminant plume as shown in the latest annual site report, however, has undergone a slight contraction.

Eleven wells (G434, G127A, G105A, 123A, and 152-158) have since been added at the site for a total of 72 monitoring wells. U.S. Ecology (1984b) has reported an additional 60 borings and wells at the HWMF. Forty-two wells, five spring sampling points, and a lake downgradient from the site are presently monitored (U.S. Ecology, 1986). Since the site is situated over a groundwater high, there are no wells upgradient of the HWMF.

Well G104 was used as a "background" well prior to the construction of well G434 which is presently used as a "background" well (fig. 28). Well G434 is believed to be located on the divide of the groundwater basin underlying the HWMF, hence, G434 should not receive groundwater from the waste trenches. All wells were constructed of PVC. Four more wells are proposed in the closure plan. In addition to installing groundwater monitoring wells, five surface-water observation points were added to the monitoring program at springs adjacent to the HWMF.

The well completion reports indicate that many wells were improperly constructed. Several wells, constructed in accordance with IEPA directives, have screens longer than 10 feet and are open to more than one unit. This construction makes it difficult to assess possible groundwater flow and

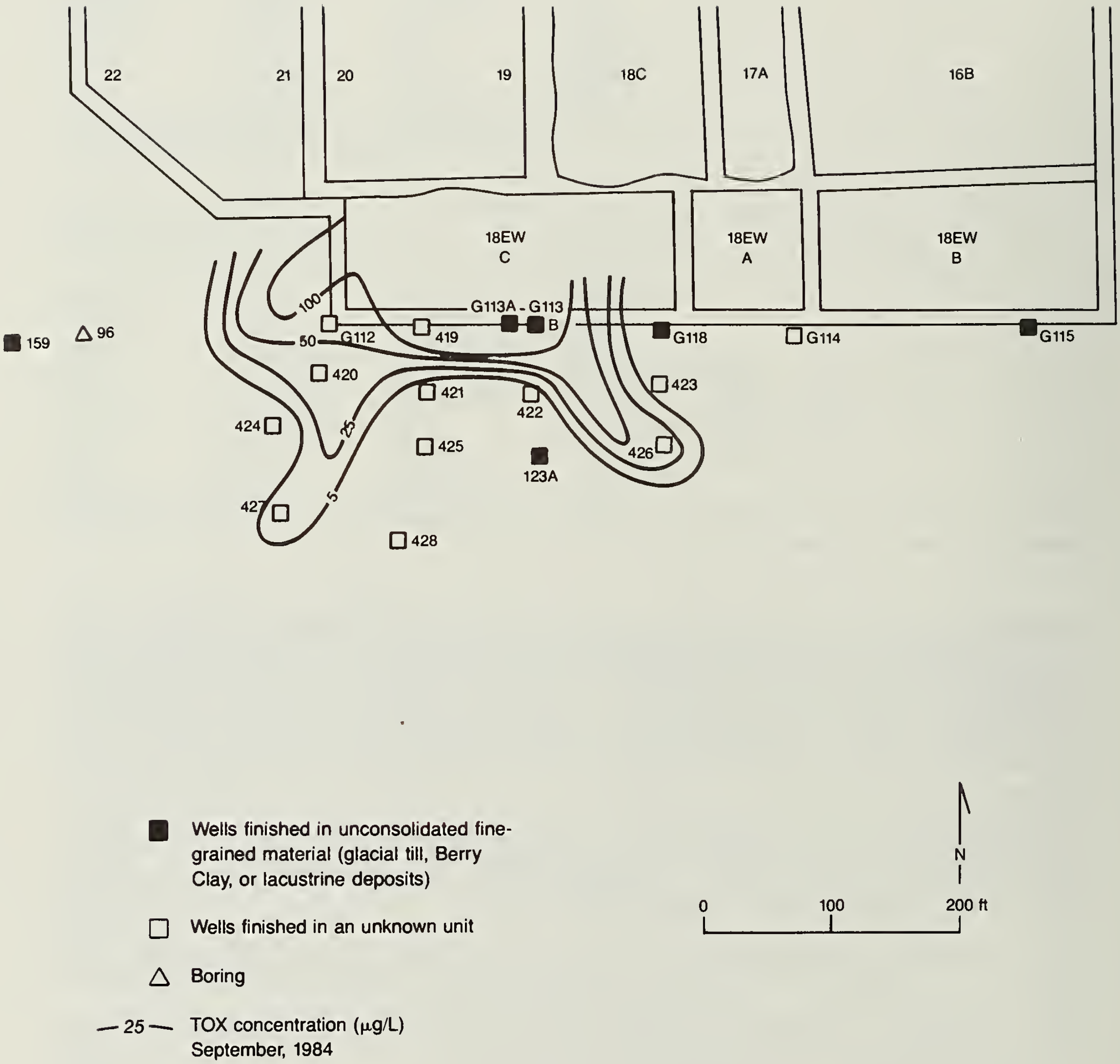

Figure 32 Map of southern portion U.S. Ecology site. Contours indicate total organic halogen (TOX) measurements as of September 1984.

contaminant transport. Many wells (including 152-162, installed outside the migration plume to better define the local geology) apparently have no annular seals, allowing hydraulic connection between geologic units and hampering assessment of contaminant migration. U.S. Ecology intends to seal wells 152-162 when "sufficient" water-level data have been collected (U.S. Ecology, 1986). At the direction of IEPA, approximately 10 percent of the wells were finished above water table in dry units, apparently to monitor the interface between the barrier wall and underlying material. These wells are useless for groundwater monitoring. In addition, poor description of geologic materials from several well borings made it difficult to determine the actual unit(s) in which several wells were finished. Construction details of several monitoring wells at the HWMF also were incomplete. For other wells, records indicate poor construction techniques. For example, wells 101-151 were constructed using glued-joint, PVC pipe. Glued joints may yield trace amounts of organic compounds which would interfere with the analysis of these parameters. These wells are not monitored. It appears that all the other wells were constructed of flush-threaded, PVC pipe, and that the annular spaces were sealed with cement, bentonite, or cement and bentonite mix (fig. 33).

Evaluation of Groundwater Monitoring Program

The 11 initial borings (five were developed as monitoring wells), conducted prior to site operation, did not adequately describe the site geology, particularly, the distribution of the Toulon Sand. When viewed with current information, the actual site-specific geologic relationships prior to site operation were uncertain because of the poor descriptions in well log and test boring data and the complex geologic nature of the site. Without an understanding of the site geology, the five initial observation points could not adequately monitor contaminant migration at the HWMF, especially since such significant indicator parameters as total organic halogen, total organic carbon, and specific conductance were omitted from the analyses. The groundwater monitoring program im-

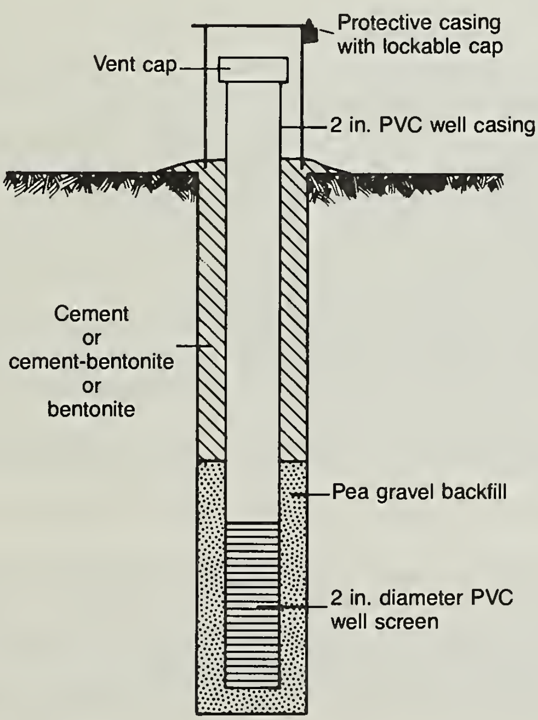

Figure 33 Typical construction of monitoring wells at the U.S. Ecology Hazardous Waste Management Facility.

proved greatly after 1980. Analyses were upgraded to include organic priority parameters. In addition, numerous monitoring wells were installed at the site when required by the regulatory agency or when assessing the distribution of the contaminant plume south of Trench 18EWC.

Examination of well installation data shows that the construction details on several monitoring wells at the HWMF are incomplete. Many wells were improperly constructed. Several wells had no annular seals, several have screens in excess of 10 feet in length, and many were finished in more than one unit or in dry units. U.S. Ecology contends that all wells were installed under strictly enforced supplemental permits which allowed little flexibility in drilling depth or construction techniques (U.S. Ecology, 1986). Many of these wells should be and, according to U.S. Ecology (1984b), will be plugged or reconstructed prior to site closure. Those wells with inadequate annular seals, which may increase the rate of contaminant migration, should also be plugged.

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U.S. Ecology, 1981, October 13 letter, S. Wright to R. Piskin: Placement of groundwater monitoring wells.

U.S. Ecology, 1982, October 8 Memo, J. Thornton to D. Fetter: Boring data for wells G196 to G199, G113A and G113B.

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SHELL OIL COMPANY-WOOD RIVER MANUFACTURING COMPLEX

Site Description

The Shell Oil Company-Wood River Manufacturing Complex is northeast of St. Louis on the eastern bank of the Mississippi River. The refinery has been operating at this site since 1917 in all or part of Sections 33, 34, 35 and 36, T5N, R9W, and Sections 2 and 3, T4N, R9W, 3PM. Currently, Shell operates one land-based hazardous waste management facility regulated by the USEPA under RCRA. This facility, a 15-acre unlined surface impoundment called the solid waste disposal basin (SWDB) (fig. 34), manages wastes generated by the effluent treatment unit and the process sewer system. Hazardous components of these waste streams include dissolved air flotation (DAF) float, slop oil emulsion solids, and API separator sludge. The majority of this waste is generated by the effluent treatment units and is listed under RCRA as hazardous due to the possible content of chromium and lead.

According to an internal Shell memorandum, leachate originating from the old fly ash pond or the SWDB was determined in 1981 to have only a marginal impact on groundwater quality (Shell, 1981). ISGS personnel visited the site in June 1985.

Geology and Hydrology

The Shell manufacturing complex is located in an area known as the American Bottoms, a nearly flat meander belt of the Mississippi River. The following discussion of geologic conditions at the site is based primarily on information from a report by Dames and Moore (1981).

The uppermost geologic unit is the Cahokia Alluvium, composed of sand, silt, and clay with some sandy gravel deposits. Alluvium is absent in some areas, but where present, it averages 6 feet in thickness (figs. 35 and 36). Underlying the alluvial deposits are the Peoria Loess and Roxana Silt units, which consist of windblown silt and average nearly 8 feet in thickness. These deposits are easily eroded and may be absent in some areas. The Mackinaw Member of the Henry Formation underlies the Peoria Loess and Roxana Silt units. The Mackinaw Member is composed of glacial outwash sands, which average 60 to 100 feet and perhaps, up to 150 feet thick. The Dames and Moore report suggests that the physical characteristics of this formation vary only slightly with depth. Hydraulic conductivity values for the Mackinaw Member, based on empirical estimates, range from 3.1×10^{-2} cm/s to 6.2×10^{-2} cm/s (Dames and Moore, 1981). These values indicate that groundwater can migrate rapidly through this sand member. The Mackinaw sands contain occasional low hydraulic conductivity lacustrine deposits of limited extent. Lacustrine deposits are primarily silts with some clays, which were deposited within the glacial outwash sequences in standing bodies of water that developed on the floodplains during late glacial and post-glacial time. Beneath the Mackinaw Member are bedrock units consisting of Pennsylvanian limestones to the east and Mississippian limestones to the west. The elevation of the bedrock surface is irregular across the American Bottoms. The depth to bedrock ranges from 110 to 170 feet below the ground surface.

The only major aquifer in the American Bottoms area, the Mackinaw Member is considered a water-table aquifer because of the absence of an extensive confining layer. The aquifer receives recharge from precipitation, snow melt, and the Mississippi River (Dames and Moore, 1981). The aquifer is a prolific source of water for towns and industry across the American Bottoms area. Shell withdraws nearly 5 million gallons of water a day. This pumping level has been sustained for many years, resulting in a well developed cone of depression beneath the refinery (Shepherd, 1983b). The direction of groundwater flow beneath the surface impoundment is controlled by the location of the production (water) wells and varies seasonally. Based on data reviewed, the groundwater beneath the surface impoundment generally flows in a westerly or northwesterly direction.

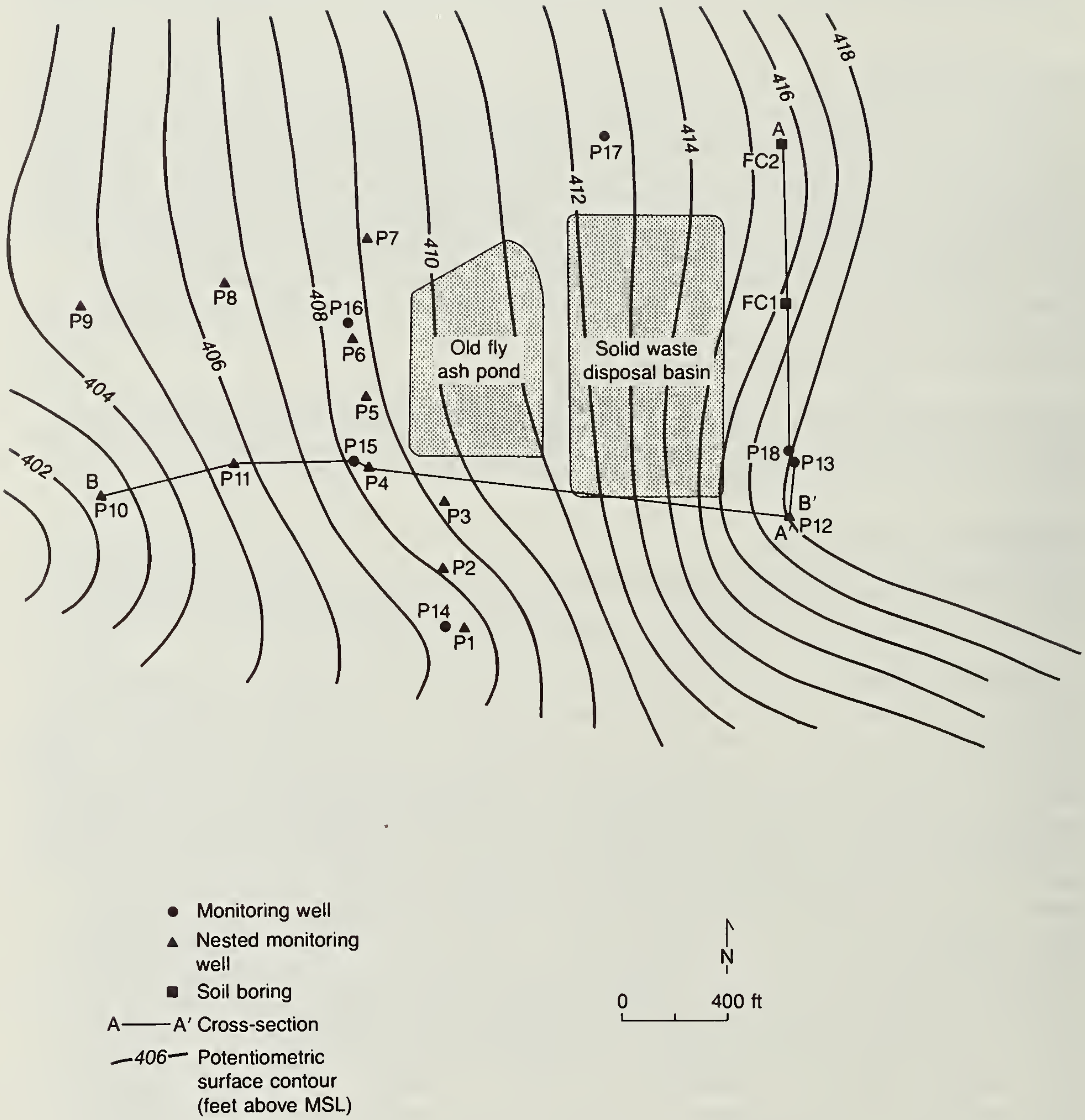

Figure 34 Map of Shell Manufacturing Complex showing disposal areas, well locations, water table elevation of the Mackinaw Sand aquifer, and lines of cross section.

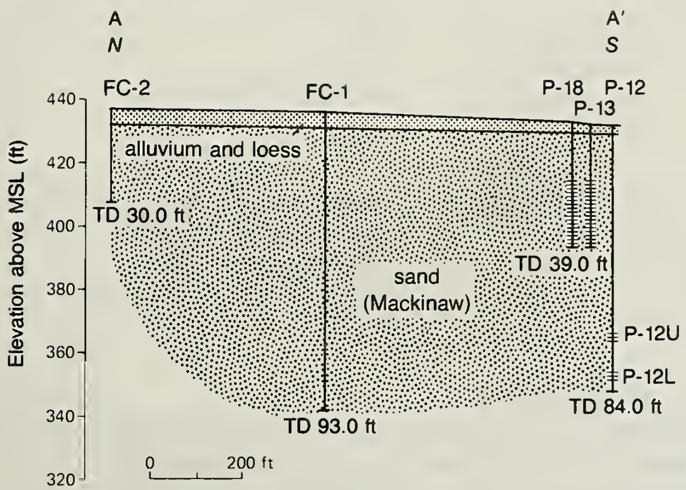

Figure 35 Shell Manufacturing Complex cross-section A-A' from north to south, east of Solid Waste Disposal Basin (adapted from Fruin-Colnon, 1972, Shepherd, 1983b, and Shell, 1985).

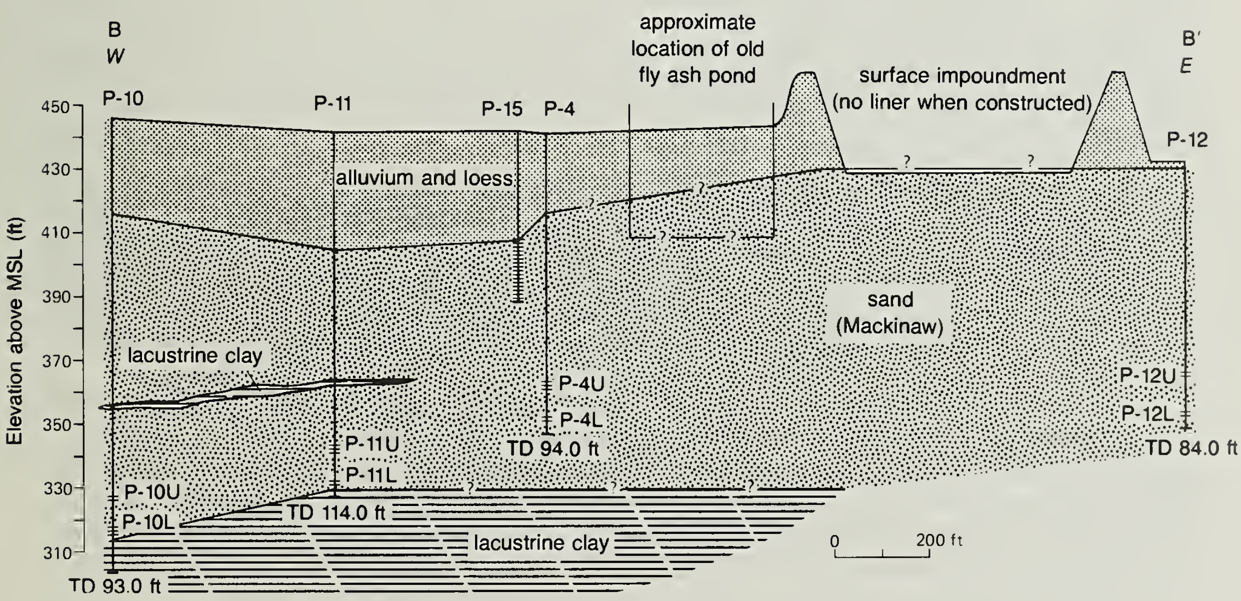

Figure 36 Shell Manufacturing Complex cross-section B-B' from west to east, south of Solid Waste Disposal Basin (adapted from Shepherd, 1983b, and Shell, 1985).

Table 13 Groundwater monitoring parameters measured at Shell, beginning in1979 (from Brewster, 1985b)

Drinking water standards (11)		*Groundwater quality parameters (6)*	
Arsenic	Lead	Chloride	
Barium	Mercury	Iron	
Cadmium	Nitrate	Manganese	
Chromium, hexavalent	Selenium	Phenols	
Chromium, total	Silver	Sodium	
Fluoride		Sulfate	
Indicators of groundwater contamination (3)		*Additional parameters (5)*	
pH		Sulfonates	Sulfide
Specific conductance (SC)		Oil and grease	Odor
Total organic carbon (TOC)		Cyanide	

Groundwater Monitoring History

Groundwater monitoring commenced in 1979 as part of an internal monitoring program using selected wells at the refinery. Shell monitored the groundwater quarterly for 11 drinking water standards, six groundwater quality parameters, three indicator parameters of groundwater contamination, and five additional parameters (table 13). In May 1981, Shell installed a multilevel monitoring network consisting of 24 wells (P1 to P12). The wells were installed in the vicinity of the old fly ash pond (OFAP) and the SWDB, which Shell considers inseparable for groundwater monitoring. The new wells were installed to determine groundwater flow patterns in the vicinity of the SWDB and, secondly, to sample the groundwater.

In November 1981, Shell petitioned USEPA Region V to waive the groundwater monitoring requirement, based on the special groundwater hydrology of the area. Shell believed that the cone of depression induced by the pumping from its groundwater production wells would contain any seepage from the SWDB area; therefore, Shell believed that the groundwater monitoring requirement should be waived. In December 1981, Shell received preliminary approval from USEPA Region V.

In January 1984, IEPA requested Shell to implement a detection monitoring program at the surface impoundment site. Shell initiated a groundwater assessment program along with the detection monitoring program. The purpose of a groundwater assessment program is to define the extent of groundwater contamination at a site once possible contamination is detected. One result of Shell's monitoring program was the installation of six additional monitoring wells (P13 to P18) to better define background conditions and provide earlier detection of groundwater contamination. In May 1984, sampling began on a quarterly basis for one year. During the detection phase, samples were collected from P12U, P1U, P4U, and P6U and analyzed for 20 drinking water standards, six groundwater quality parameters, and four indicators of groundwater contamination (table 14). During the assessment phase, Shell collected samples from P1U, P4U, P6U, P12 (U and L) and P13 to P18, which were analyzed for organics, metals, cyanides, and sulfides for one year. When the analysis was completed, Shell reportedly proposed a maintenance assessment monitoring system for IEPA approval.

Preliminary results of the monitoring to date indicate higher downgradient concentrations of TOC, iron, barium, and lead when compared with upgradient concentrations (Shell, 1984b). The significance of these higher concentrations cannot be assessed until the entire first year data are reviewed. Results from 1981 indicate high concentrations of chloride and sulfate in the lower portion of the aquifer, which were reported by Shell to have only a marginal impact on the groundwater quality.

Table 14 Groundwater monitoring parameters measured at Shell, beginning in 1984 (Shell, 1984b and Brewster, 1985b)

Drinking water standards (20)			*Groundwater quality parameters (6)*
Arsenic	Nitrate	2, 4-D	Chloride
Barium	Selenium	2, 4, 5-TP (Silvex)	Iron
Cadmium	Silver	Radium	Manganese
Chromium	Endrin	Gross alpha	Phenols
Fluoride	Lindane	Gross beta	Sodium
Lead	Methoxychlor	Coliform bacteria	Sulfate
Mercury	Toxaphene		
Indicators of groundwater contamination (4)			
pH			
Specific conductance (SC)			
Total organic carbon (TOC)			
Total organic halogen (TOX)			

Figure 37 shows the two main types of monitoring wells installed. The well type installed in 1981 (P1-P12) and the type installed in 1984 (P13-P18) vary only in the length of the screen. The 1981 wells use 2-foot length screen; the 1984 wells have 20-foot length screens. The 1984 wells were installed at the water table because Shell believed any groundwater contamination would become apparent at this location. The use of the 20-foot screens seems justified due to the variability of the water table elevation. The 1981 wells were installed deeper in the aquifer. Because the aquifer is quite permeable and remains saturated at the screened intervals, the use of 2-foot screens seems appropriate since an adequate sampling volume can be obtained.

Limited information about the waste placed in the SWDB, and none regarding the waste contained in the OFAP, make it difficult to judge the appropriateness of the parameters monitored. In reviewing the preliminary analytical results, however, it appears that specific conductance, a gross indicator of inorganic contamination, cannot be used solely to detect significant concentrations of individual toxic chemicals. For example, 10 mg/L (milligrams per liter) of barium could easily go unnoticed if only specific conductance was monitored because the barium ions comprise only a minor percentage of the total ions present in the groundwater. Therefore, additional parameters should be monitored in the detection monitoring program. However, IEPA states that RCRA regulations specify detection monitoring parameters. The Illinois Environmental Protection Agency does not have authority to select these parameters (IEPA, 1985).

Evaluation of Groundwater Monitoring Program

The presence of the old fly ash pond (OFAP) adjacent to the regulated, solid waste disposal basin (SWDB) complicates the evaluation of the groundwater monitoring system because no records of the waste disposed in the OFAP were available. Also, due to the nature of the OFAP, installation of monitoring wells immediately downgradient from the SWDB is not possible. Therefore, any contaminants originating from the SWDB may be significantly diluted by the time they are detected by the downgradient monitoring wells. However, any detected release will be attributed to the SWDB, regardless of its source, unless Shell can conclusively prove otherwise (IEPA, 1985).

Currently, Shell uses four wells for detection monitoring, and 11 wells for assessment monitoring. Based on the groundwater flow information reviewed, the wells used for the detection monitoring program should be modified. The current set of detection wells (P1U, P4U, P6U, and P12U) are not properly located to immediately detect all probable pathways of groundwater contamination.

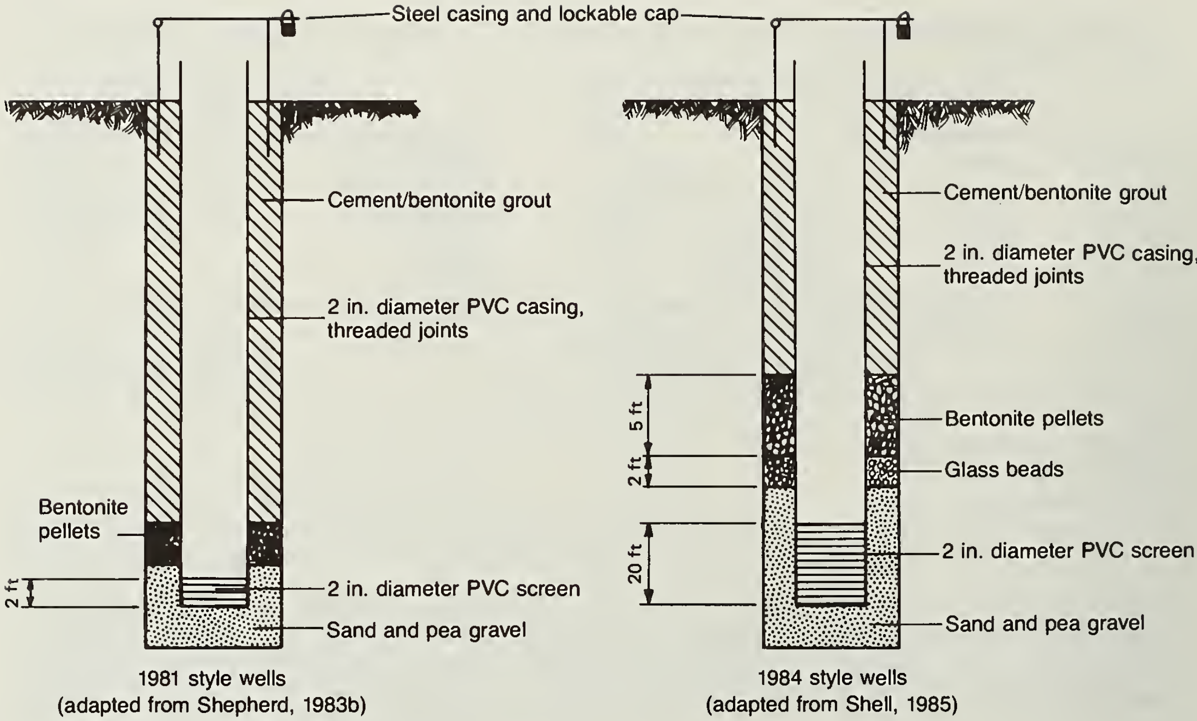

Figure 37 Typical construction of monitoring wells at Shell Manufacturing Complex.

The design and construction of the monitoring wells installed in 1981 and 1984 seem adequate for their respective application. A significant concentration of one inorganic ion at this site could easily be masked by other ions present in the groundwater. Therefore, the use of specific conductance as the sole indicator is probably not adequate for detecting all cases of inorganic contamination.

Sources of Information

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MARATHON PETROLEUM COMPANY-ROBINSON REFINERY

Site Description

Marathon Petroleum Company operates a petroleum refinery immediately east of Robinson in Crawford County in all or parts of Sections 2 and 3, T6N, R12W, and Sections 34, 35, and 36, T7N, R12W, 2PM. The refinery operates four regulated, land-based hazardous waste management facilities, which consist of a 17-acre land treatment site (landfarm) and three surface impoundments, all located within the same area of the refinery (figure 38). Two of the surface impoundments--the 467,000 gallon, dissolved air flotation (DAF) skimmings pit and the 290,000 gallon, oily sludge pit--store waste when climatic conditions prohibit application of the waste onto the landfarm, a treatment and disposal facility. Wastes applied to the landfarm and stored in the two surface impoundments include the following materials, classified as either hazardous (H) or nonhazardous (NH) wastes by IEPA: DAF skimmings (H), slop oil emulsions (H), HF alky sludge (NH), API separator sludge (H), heat exchanger bundle cleaning sludge (H), waste biosludge (NH), unleaded tank bottoms (NH), and various sludges (NH).

The third surface impoundment, a 20,000 gallon bulk-waste pit, stores leaded tank bottoms prior to shipment for off-site disposal. Unlike the two other impoundments which are unlined, this impoundment is lined with a 20-millimeter thick, Hytrel polyester geomembrane.

Marathon plans to expand the landfarm from its current size of 17 acres to 40 acres; however, these expansion plans have not been permitted by the appropriate regulatory agencies.

Marathon officials denied the ISGS evaluation team a visit to the refinery.

Geology and Hydrology

The Marathon refinery is located in an area of gently sloping (2%) topography. The ground surface slopes to the north and northeast. The depth to bedrock averages 25 to 50 feet and, in some locations, is only 20 feet (Dames and Moore, 1981a). Dames and Moore has described two distinct, unconsolidated geologic units overlying the bedrock (figures 39 and 40). At the surface, 5 to 10 feet of loess cover the underlying till. The loess deposits generally become thicker toward the east. The underlying till is the Vandalia Till Member of the Glasford Formation. This Illinoian age till has a silty clay texture with little sand and gravel. In the vicinity of the refinery, there are no known water supply wells completed in the Vandalia Till; however, on-site borings indicate that sand lenses exist within the till (Dames & Moore, 1981a). Laboratory tests reveal that the till has a very low hydraulic conductivity, 1×10^{-7} cm/s (Dames and Moore, 1981b). Dames and Moore (1981a) reported the following geologic information. The uppermost bedrock formation is the Mattoon Formation of the Pennsylvanian System. The formation consists of a complex sequence of limestones, coals, fissile black shales, thick gray shales, and several well-sorted sandstones. In the vicinity of the refinery, the uppermost bedrock unit of the Mattoon Formation is a sandstone layer. The top of this sandstone unit slopes downward from a local high situated near monitoring well B2. Generally the upper 5 feet of this sandstone are weathered to a loose sand. Reported hydraulic conductivity values for the weathered portion of the sandstone range from 3.0×10^{-4} to 1.8×10^{-5} cm/s. These moderate to low conductivity values were determined from field (slug) tests of four on-site monitoring wells. The slug tests were analyzed using Hvorslev's method.

The sandstone unit yields groundwater supplies sufficient for domestic use. Several wells within a quarter mile radius of the landfarm are finished in this sandstone (Dames and Moore, 1981b). This aquifer may be under confined conditions due to the relatively impermeable nature of the overlying till unit. Figure 38 shows the potentiometric surface of the sandstone aquifer. The direction of groundwater flow in the sandstone aquifer varies seasonally from the northeasterly direction as shown in figure 38 to due north (Radian, 1984). Groundwater elevations also vary seasonally by approximately 4 to 8 feet (Radian, 1984).

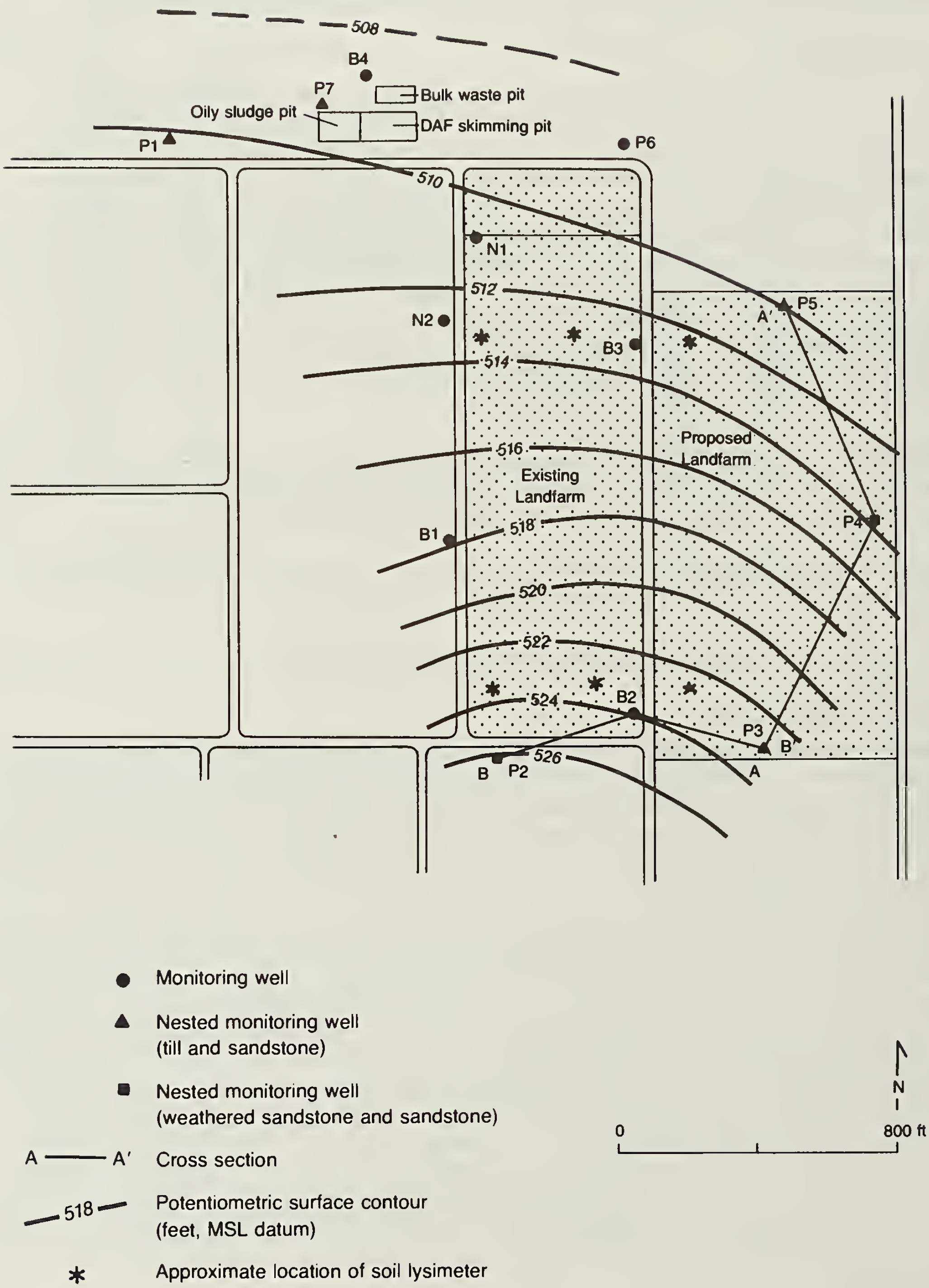

Figure 38 Map of Marathon refinery showing disposal areas, well locations, potentiometric surface of the sandstone aquifer, and lines of cross section (from Radian 1984).

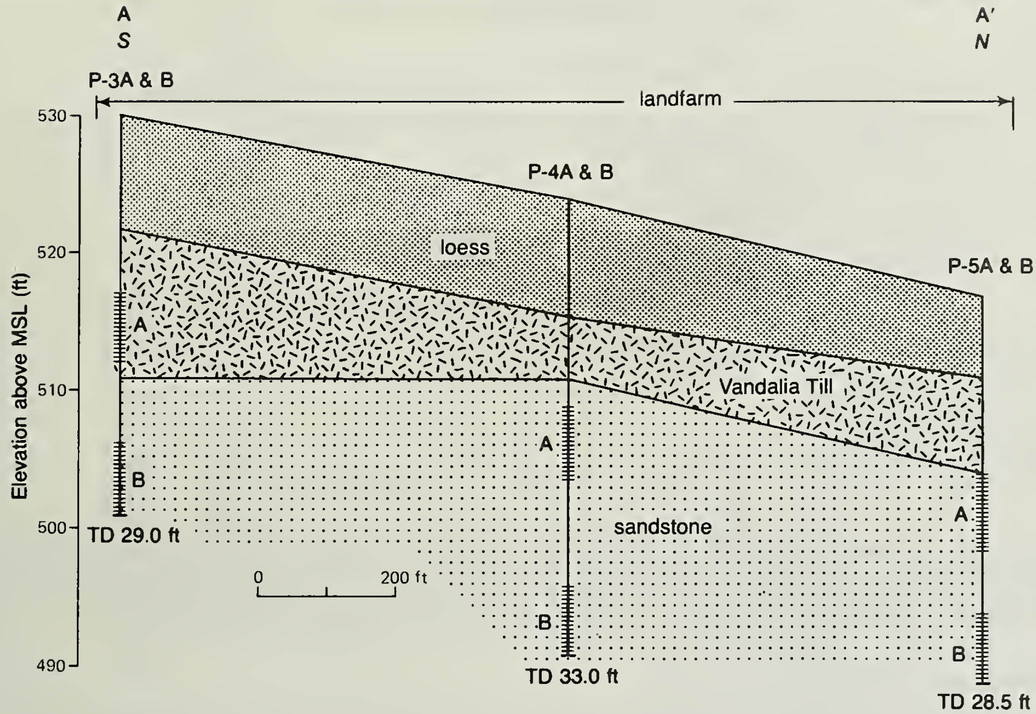

Figure 39 Marathon refinery cross section A-A' from south to north, east of landfarm (adapted from Radian, 1984).

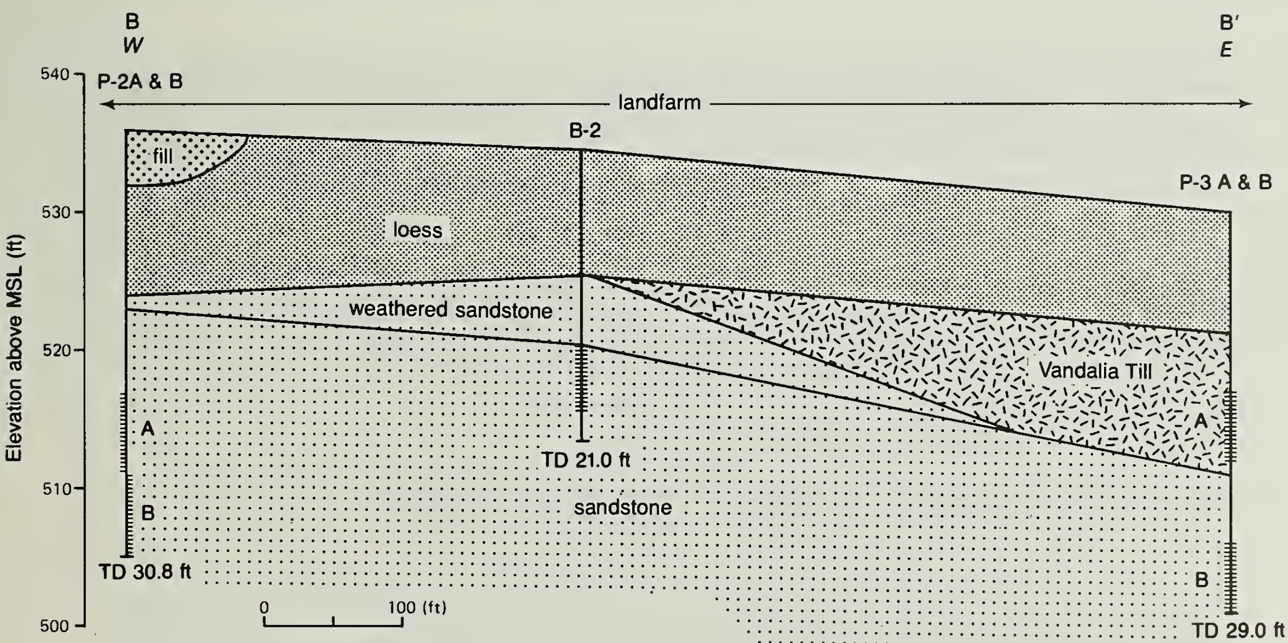

Figure 40 Marathon refinery cross-section B-B' from west to east, south of landfarm (adapted from Dames & Moore, 1981b and Radian, 1984).

Table 15 Groundwater monitoring parameters used at Marathon beginning in 1982 (from Dames and Moore, 1981c)

Drinking water standards (21)			*Groundwater quality parameters (6)*
Arsenic	Nitrate	2,4-D	Chloride
Barium	Selenium	2,4, 5-TP (silvex)	Iron
Cadmium	Silver	Gross alpha	Manganese
Chromium	Endrin	Gross beta	Phenols
Fluoride	Lindane	Radium 226	Sodium
Lead	Methoxychlor	Radium 228	Sulfate
Mercury	Toxaphene	Coliform bacteria	
Indicators of groundwater contamination (4)			
pH			
Specific conductance (SC)			
Total organic carbon (TOC)			
Total organic halogen (TOX)			

Although the sandstone layer yields domestic water supplies, no major aquifers are in the vicinity of the site. The Town of Robinson receives its water supply via an 8 mile pipeline from wells finished in unconsolidated sand and gravel aquifers along the Wabash River.

Groundwater Monitoring History

During fall 1981, six monitoring wells were installed near the hazardous waste management area. Sampling of these wells began in March 1982 and continued quarterly for one year. The samples were analyzed for 21 drinking water standards, six groundwater quality parameters, and four indicators of groundwater contamination, which provided background quality data (table 15). Since completion of background sampling and analyses in 1983, samples have been collected and analyzed annually for groundwater quality parameters and semiannually for indicators of groundwater contamination.

In March 1984, Marathon started the process of re-establishing background quality of the groundwater. The previous background data were reportedly invalid because of erroneous sampling procedures and test results. During the re-establishment process, samples were analyzed quarterly for 21 drinking water standards, six groundwater quality parameters, and four indicators of groundwater contamination. In addition, samples from two downgradient wells were analyzed for priority pollutants.

Twelve more wells were installed in fall 1984 to monitor the proposed landfarm expansion and correct a deficiency in the previous (1981) monitoring network, which had an improperly placed upgradient well. Ten of the wells were installed as nested pairs (two wells of different depths at the same location) and several were incorporated into the groundwater monitoring program. Samples from two upgradient wells (P2B and P3B) and five downgradient wells (B4, P4B, P5B, P6 and P7) were analyzed for the same 31 parameters.

This portion of the groundwater monitoring program is currently under review by IEPA and USEPA. Changes in the monitoring system seem likely in the near future.

The records reviewed did not indicate any confirmed reports of contamination of the sandstone aquifer by any of the monitored parameters. The only confirmed report of contaminated samples was from soil-water samplers (lysimeters) at unknown depths. Taken in 1983, these sample had elevated concentrations of arsenic and fluoride.

The soil lysimeters were installed to monitor the vadose zone below the landfarm as required by regulations. The purpose of the vadose zone monitoring system is to check the effectiveness of

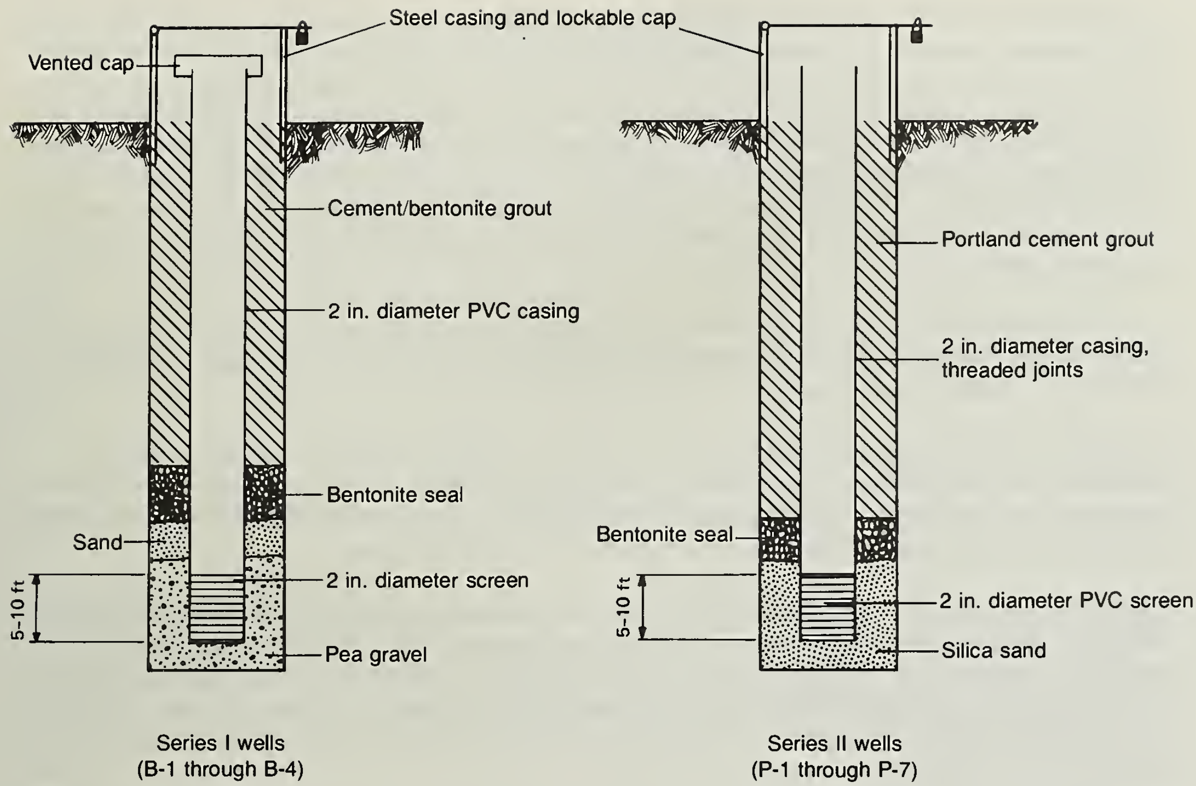

Figure 41 Typical construction of monitoring wells at the Marathon refinery (adapted from Dames and Moore, 1981b and Radian, 1984).

the landfarm in treating the applied waste. Figure 38 shows the approximate locations of the six lysimeters, two of which supply background data. Since very little is known about the lysimeter installations, additional information is necessary to make a complete evaluation.

Figure 41 shows the two types of monitoring wells installed at the Marathon refinery. The PVC casing of the series II wells is connected by threaded joints. The casing of the series I wells also is reportedly connected by threaded joints (Saad, 1986). The length of the well screen for both series of wells is either 5 or 10 feet. The use of longer well screens appear unnecessary. Most of the wells constructed with the 10 foot screens are completed in two or more types of geological material, which is generally considered a poor practice.

Marathon considers the chemical analyses of the wastes handled by the four hazardous waste management facilities confidential, and therefore provided very little of this information for this study (Marathon and Radian, 1984). By RCRA definition, the majority of the waste handled by Marathon is considered hazardous because of its chromium and/or lead content. Marathon uses pH, specific conductance, total organic carbon, and total organic halogen as indicators of groundwater contamination; these parameters are gross indicators of contamination. Specific conductance (SC) only gives a gross indication of inorganic contamination. It seems that significant concentrations of chromium and/or lead may not impact the SC measurement due to the relative magnitude of the SC value. Therefore, chromium, lead or any other significant, inorganic waste component should be added to the list of indicators of groundwater contamination.

Evaluation of Groundwater Monitoring Program

The hazardous waste management facilities (the landfarm and three surface impoundments) should not be monitored as one unit (the current practice), since the upgradient wells are too far away to provide reasonable background quality data for the groundwater beneath the surface impoundments. Rather, the facilities should be treated as two units: the land treatment facility and the three surface impoundments. One ramification of this proposal is that additional monitoring wells, both upgradient and downgradient, would be needed for the surface impoundment unit. Based on a review of the site's groundwater hydrology, at least one downgradient well should be located east of well B4.

The groundwater monitoring system for the existing landfarm is inadequate. Well P4B is too far away from the landfarm boundary to immediately detect groundwater contamination. Likewise, P5B is only marginally adequate.

Marathon and IEPA agree that the top of the sandstone aquifer should be monitored; however, Marathon monitors the deeper of the nested wells (i.e., Marathon uses P2B instead of P2A). The boring logs and well construction records reveal that most A-series nested wells (P1A, P2A, etc.) would be more suitable for monitoring the top of the sandstone aquifer.

Studies should be undertaken to determine if the sand lenses within the till are hydraulically connected to the underlying sandstone. If hydraulic connection exists or the lenses are found to be extensive, modifications will be required in the groundwater monitoring system. Additional information is required to evaluate the vadose zone monitoring for the land treatment facility. This information would probably have to be supplied by Marathon, which cooperated on a very limited basis during this study.

The design and construction of the series II monitoring well with a five-foot screen seems adequate for its application. At least two parameters, chromium and lead, whose content cause the waste to be classified as hazardous, should be added to the list of indicators of groundwater contamination because analysis of specific conductivity may not be capable of indicating a significant concentration of either parameter.

The Marathon Petroleum Company, given an opportunity to comment on a draft of this report, responded that the deficiencies noted in the draft report were incorrect and that the current groundwater monitoring system was adequate. When requested to furnish documentation to substantiate these opinions, Marathon did not respond; therefore, the company's comments were not incorporated into the final report. During the final review of the report in June 1986, Marathon indicated that significant, new information became available by early 1986. The ISGS evaluation team, unaware of the new information, did include it in this report.

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Dames and Moore, 1981c, Hydrogeologic Investigation, Phase III of III. 4 p.
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Saad, David R., 1986, personal communication, June 2, 1986.
Correspondence between Marathon and IEPA.
Records, memos, etc. from IEPA files.

TEXACO OIL REFINERY-LAWRENCEVILLE

Site Description

Texaco, Inc. operated a petroleum refinery immediately south of Lawrenceville in Lawrence County in all or parts of Sections 5, 6, 7 and 18, T3N, R11W, and Section 12, T3N, R12W, 2PM. The refinery closed in April 1985, reportedly for economic reasons. When the refinery was in operation, Texaco utilized two land-based, hazardous waste management facilities composed of a 30-acre landfarm and a surface impoundment (fig. 42). The actual working area of the landfarm shown in figure 42 is considerably smaller than 30 acres. The wastes managed at the landfarm include API separator sludge and slop oil emulsion solids, as well as minor amounts of leaded tank bottoms and heat exchanger cleaning sludge. Corrosive wastes, managed at the surface impoundment, were derived from petroleum refining processes and are considered hazardous due to the probable content of lead and chromium and due to corrosivity.

According to the CERCLA Superfund File, groundwater contamination is suspected at this site. Since the refinery is not in operation, the ISGS team did not visit.

Geology and Hydrology

The refinery site, adjacent to the Embarras River, is in an area of low relief and broad terraced valleys with low gradient streams (ATEC, 1981). The site consists of an upland and a lowland approximately 10 feet lower, divided by a northeast-southwest trending bluff. The upland generally consists of post-glacial deposits such as loess, eolian sands, lacustrine, and alluvial deposits overlying an Illinoian till surface (figs. 43, 44, and 45), (ATEC, 1981). Eolian sands are absent in these cross sections, but this type of deposit has been found by others in borings at the refinery. The loess, also not shown in the cross sections, has been modified by soil formation, eroded in places, and redeposited as alluvium. As shown in figure 43, the landfarm is located on the upland.

The aeration lagoon is in the lowland, east of the bluff. The lowland is characterized by recent alluvial deposits of the Embarras River (ATEC, 1981). Figure 45 shows alluvium overlying glacial outwash sands, which overlies Illinoian glacial till.

The following geologic information is based on a report prepared by ATEC in 1981. The bedrock underlying the unconsolidated deposits is the Bond Formation of the Pennsylvanian System. Depth to bedrock averages 25 to 50 feet across the site and tends to increase toward the modern Embarras River to the east. In southeastern Illinois, the Bond Formation is approximately 3,000 feet thick and dips southwest toward the center of the Illinois Basin. The upper portion of the formation is typically shale, but in the area of the refinery, the uppermost bedrock unit consists mainly of sandstone, a locally significant aquifer. As illustrated in figure 42, the direction of groundwater flow in this aquifer is generally southeast toward the Embarras River, but there is also a southwesterly component near the western half of the landfarm (Texaco, 1984).

The principal aquifers in the vicinity of the site include sand and gravel lenses in the glacial drift and extensive deposits of outwash sand and gravel in the valleys. Wells in the outwash sand and gravel deposits have reported average yields of 50 to 100 gpm. A shallow, eolian sand layer serves as a secondary aquifer in the upland. Several low-yield, domestic wells are completed in this unit.

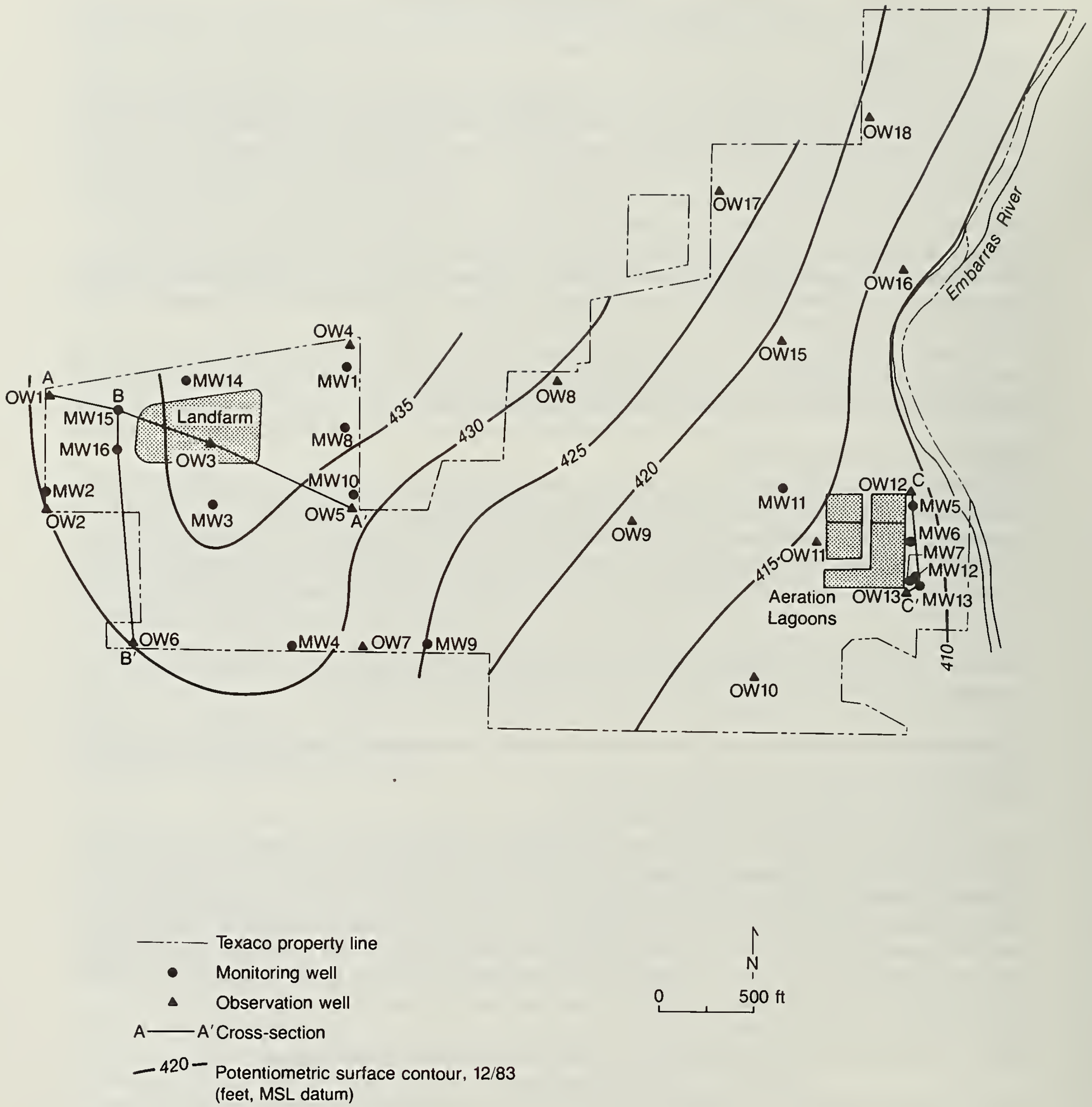

Figure 42 Map of Texaco refinery showing disposal areas, well locations, potentiometric surface of two hydraulically connected sand layers, and lines of cross section.

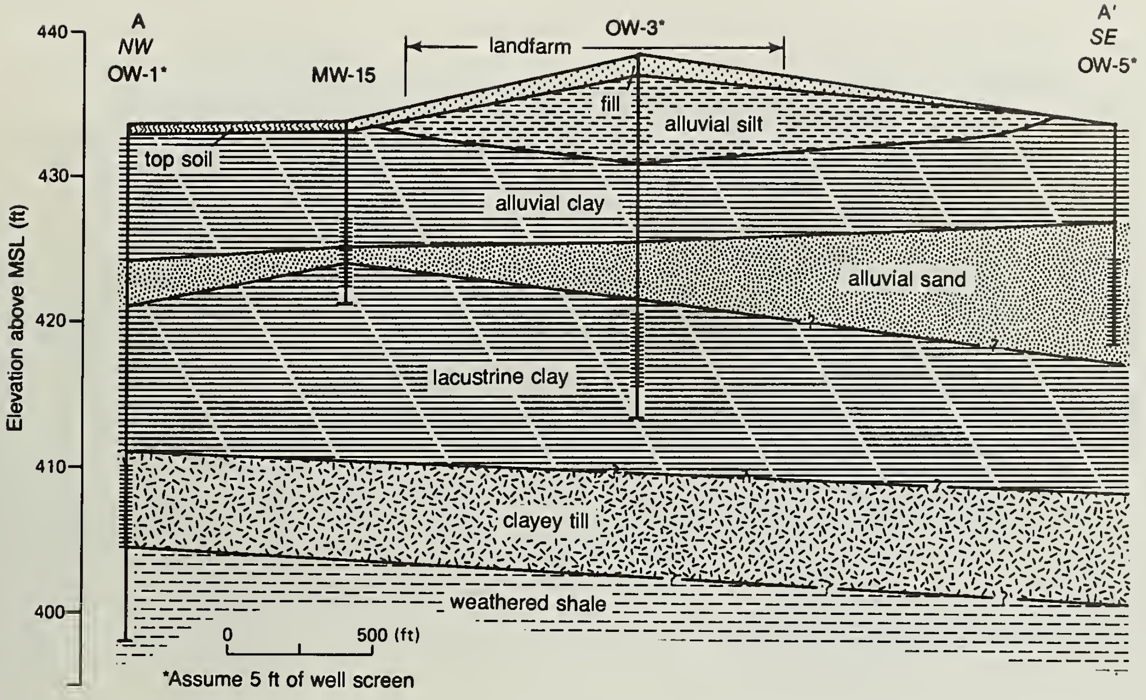

Figure 43 Texaco refinery cross section A-A' from northwest to southeast through the landfarm (adapted from ATEC, 1981 and Texaco, 1984b).

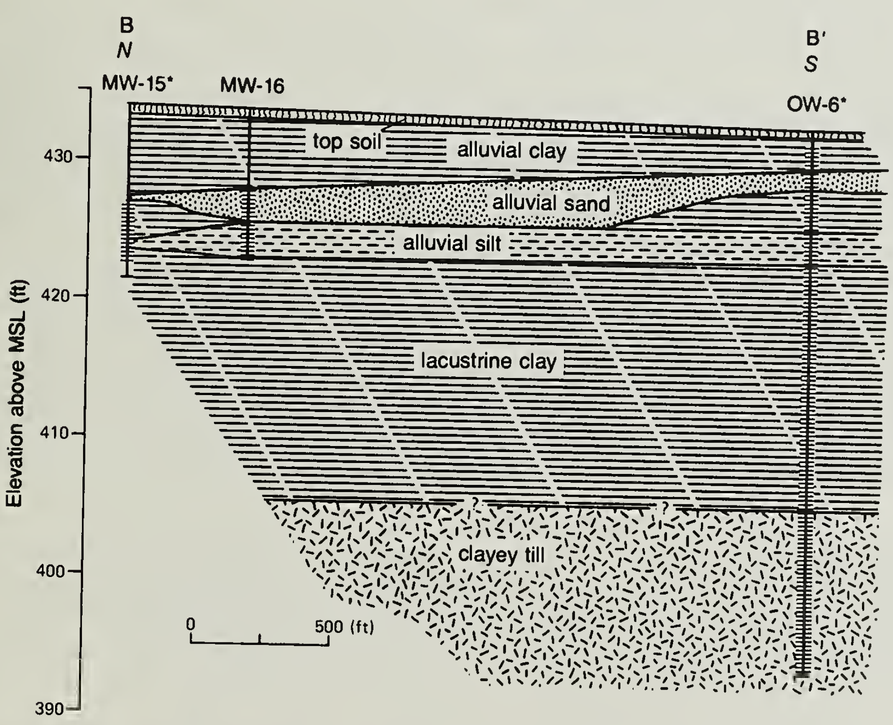

Figure 44 Texaco refinery cross-section B-B' from north to south, west of landfarm (adapted from ATEC, 1981 and Texaco, 1984b).

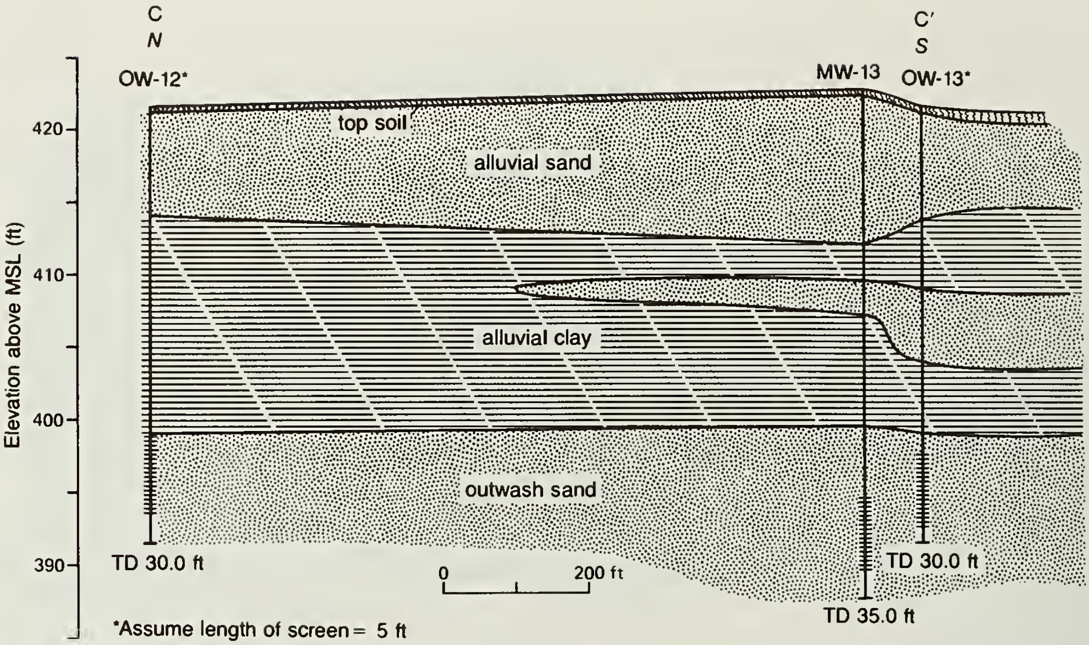

Figure 45 Texaco refinery cross-section C-C' from north to south, east of the surface impoundment (adapted from ATEC, 1981 and Texaco, 1984b).

Groundwater Monitoring History

Groundwater monitoring near the hazardous waste management facilities began in 1982 after the installation of monitoring wells, MW1 to MW10. Samples from the ten wells were analyzed quarterly for pH, SC, TOC, TOX, fecal coliform, metals (including lead and chromium), phenols, chloride, sulfate, nitrate, pesticides, and radioactivity (Jones, 1986). In 1983, sampling and analysis for the first four parameters were conducted on a semiannual basis. The analytical results of these samples were compared with the background (1982) values using the Student's t-test method. Results of the comparison showed a "significant increase (or pH decrease)" for the May 1983 samples, indicating degradation of groundwater quality. Texaco, therefore, analyzed the December 1983 samples for assessment parameters which included pH, SC, TOC, TOX, lead, and chromium (total). In 1984, Texaco installed six monitoring wells (MW11-16) to correct several deficiencies. The new wells were designed to determine more realistic upgradient groundwater conditions and detect contamination in a "perched" water zone beneath the surface impoundment and in the area west of the landfarm, which was not adequately monitored. Since October 1984, samples from these wells have been analyzed for background contamination parameters: pH, SC, TOC, TOX, lead, and chromium (total). Texaco reported that additional parameters are monitored, but provided no specific information for this study (Jones, 1985).

Vadose zone monitoring is required for the landfarm. Figure 42 shows the locations of seven lysimeters (including L7, a background lysimeter). Samples taken from the soil water lysimeters are analyzed for pH, SC, TOX, TOC, phenols, nitrate, lead, and chromium (Jones, 1985). Since no sampling results were available, evaluation of the vadose zone monitoring system was not possible. The vadose zone monitoring system, however, reportedly meets RCRA standards (Jones, 1985).

Currently, the original set of monitoring wells (MW1-10) is apparently monitored for at least 10 parameters on a semiannual basis. The second set is monitored quarterly for at least six parameters. This level of monitoring will apparently continue until modified by the groundwater monitoring requirements of the refinery's closure plan.

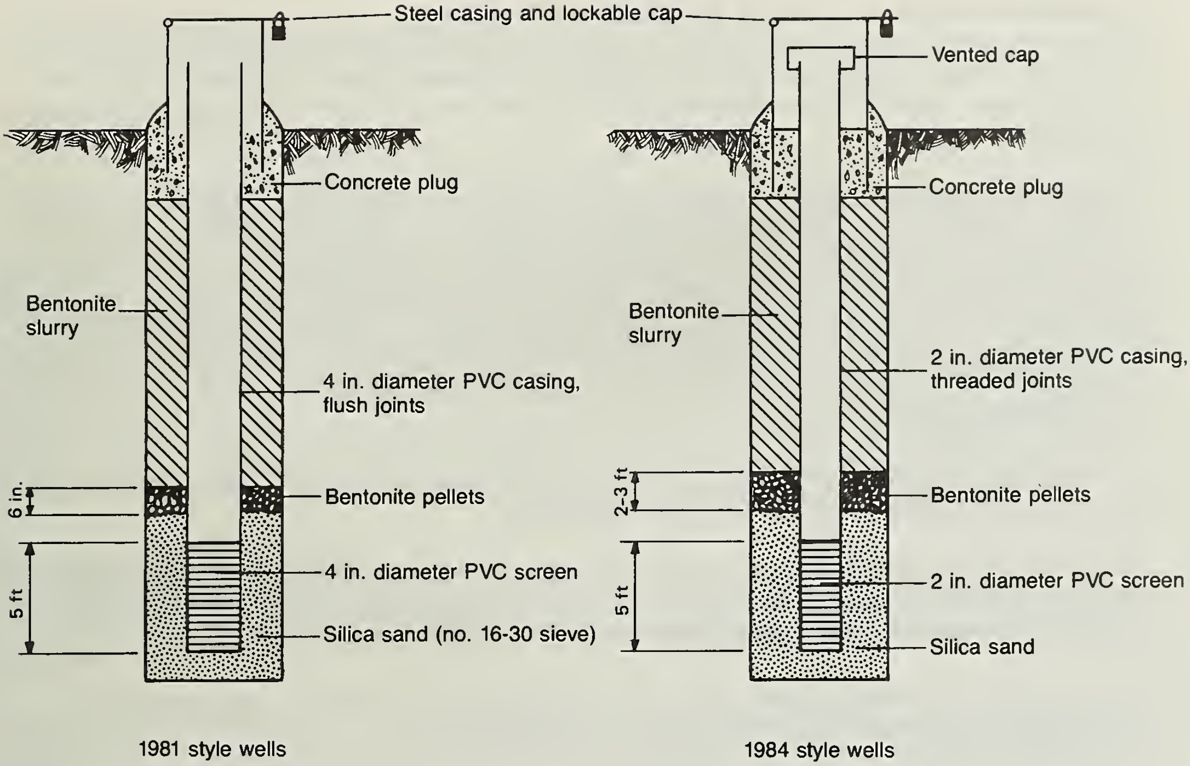

Figure 46 Typical construction of monitoring wells at the Texaco refinery (ATEC, 1981 and Texaco, 1984b).

According to the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) Superfund File compiled by USEPA, groundwater contamination at the site is suspected. A review of the available records showed that the groundwater monitoring system has occasionally detected elevated concentrations of various parameters, but no parameters have been detected at elevated concentrations on a consistent basis.

Figure 46 shows two basic types of monitoring wells: the 1981-style wells (MW1 to MW10), constructed of 4-inch PVC casing and screens with flush joints (which were not glued) and the 1984 style wells (MW11 to MW16), which improved on the design of the earlier wells by reducing the diameter to 2 inches. Proper sampling protocol requires extracting three to five well volumes before a sample is taken. The 4-inch wells require four times more water to be removed than the 2-inch wells. Thus, the larger diameter (4-inch) wells are probably less suitable than the smaller diameter wells for this situation, particularly near the landfarm. Overall, the 1984 style wells are adequate for the designed purpose.

Based on very limited information about the chemistry of the waste, it seems that most waste disposed of and treated is organic and contaminated with lead and/or chromium. Therefore, TOC, lead, and chromium (total) appear to be obvious candidates for indicator parameters. In this light, the revised list of indicator parameters (pH, SC, TOC, TOX, chromium (total), and lead) seems appropriate; the original list, which did not include lead and chromium, was inadequate. Specific conductance (SC) is a gross indicator of inorganics, and significant concentrations of lead and/or chromium would probably be masked by background SC values. Additional information is required to evaluate the appropriateness of the other monitored parameters.

Evaluation of Groundwater Monitoring Program

The closing of the refinery hampered the evaluation of the groundwater monitoring program. Texaco personnel, deeply involved with closing activities, were unable to provide the assistance and information needed to thoroughly evaluate the groundwater program. Hence, the following is a limited assessment.

A ridge of groundwater is present below the landfarm, which causes the groundwater in this area to flow in a westerly, southerly and southeasterly direction. The installation of MW14, MW15 and MW16 improved the system's capability of monitoring the westerly component of groundwater flow. Wells monitoring groundwater flow to the south and southeast may be too far away from the the landfarm to immediately detect groundwater contamination. An observation well (OW3) is in the middle of the landfarm. According to Jones (1986), OW3, as well as OW5, OW6, OW12 and OW13, were cement grouted in compliance with requirements stipulated by the Illinois Department of Mines and Minerals.

RCRA regulations require the landfarm to have vadose zone monitoring. Limited information concerning this monitoring made an evaluation impossible.

The groundwater monitoring system for the surface impoundment focuses on the deeper, outwash sand, but there are two permeable zones above this unit (figs. 43 to 45) that may require monitoring. Additional information is required to make a proper evaluation of this site.

The indicator parameters (pH, SC, TOC, TOX, chromium (total), and lead) appear to be appropriate based on the information available for this study.

The 1984 style monitoring wells seem adequate to suit the designed purpose; however, the earlier well design is probably less suitable because of the larger diameter.

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FRINK'S INDUSTRIAL WASTE

Site Description
Frink's Industrial Waste storage facility is located on four acres of land 2 miles north of the Village of Pecatonica, Winnebago County. Operations at the storage site began in 1975. IEPA granted a permit for waste storage in 1979. The site has had 17 storage tanks with capacities ranging from 3,000 to 21,000 gallons and two lagoons with storage capacities of approximately 200,000 gallons in operation. Liquid wastes stored at the facility have included waste oils, metal-bearing liquids, and solvents. Underground storage tanks were located in three areas: four tanks beneath a tank treatment building in the center of the site, 11 tanks along the southern boundary, and two tanks between the other tank locations (fig. 47). Tanks 16 and 17 (fig. 47) were excavated and removed, and tanks 5 to 15 were emptied, cleaned, and filled with sand. The Frink's site, which was expected to close in 1986, has not received bulk waste for storage since September, 1985 (Shriver, 1986). Because of pending litigation, company management denied ISGS personnel a visit to the facility for this report. ISGS staff had visited the site prior to this study, however.

Geology and Hydrology
The Frink's Industrial Waste is located on the edge of an upland 1.5 miles north of the Pecatonica River. Surface-water drainage is toward the river, which is more than 50 feet below the elevation of the site.

The uppermost geologic unit at the site is a layer of Peoria Loess which ranges from a few feet to more than 15 feet in thickness. Beneath the loess are 20 to 60 feet of unconsolidated glacial deposits consisting of glacial till underlain by a layer of clayey silt. The glacial till is assigned to the Ogle Till Member of the Glasford Formation. Ogle Till generally is a tan to gray brown, sandy silt to silty clay containing numerous thin, discontinuous beds of sand and gravel. Weathering of the till prior to deposition of the loess resulted in the development of a paleosol in the upper portion of the till.

Bradbury (1984) indicated that a fairly continuous layer of water-bearing sand and gravel was present within the till at the Frink's site. This unit was reported to be 1to 5 feet thick and located at a depth of 25 to 30 feet below ground surface. More recent borings examined by IEPA and ISGS, however, suggest that this permeable sand and gravel is discontinuous. The discrepancy may result from the vague and confusing descriptions of geologic materials provided in the driller's boring logs for boreholes made prior to 1984 (ISGS, 1984). Figures 48 and 49 show interpretations of geologic relationships constructed primarily from IEPA and ISGS data. The data suggest that the thickness of unconsolidated glacial material increases to the southeast.

Typically, these unconsolidated glacial deposits are not water-yielding, but a significant quantity of water may flow through the thin, discontinuous sand and gravel beds and through fractures in the till. Recent hydrologic data suggest that groundwater in this shallow unconsolidated groundwater system generally flows from northeast to southwest.

Underlying the till is dolomite bedrock of the Galena-Platteville Groups. The bedrock units are estimated to be 100 to 200 feet thick in the vicinity of the Frink's site and to dip to the south-southeast. This fractured dolomite acquifer is an important regional source of domestic groundwater. The degree of fracturing within the dolomite unit controls groundwater flow and the quantity of available water. Hydrologic data, although sparse, suggest that groundwater within the Galena-Platteville dolomites flow from northwest to southeast (fig. 47). Below the Galena-Platteville Groups are three major aguifer units: the Ancell Group, the Ironton-Galesville

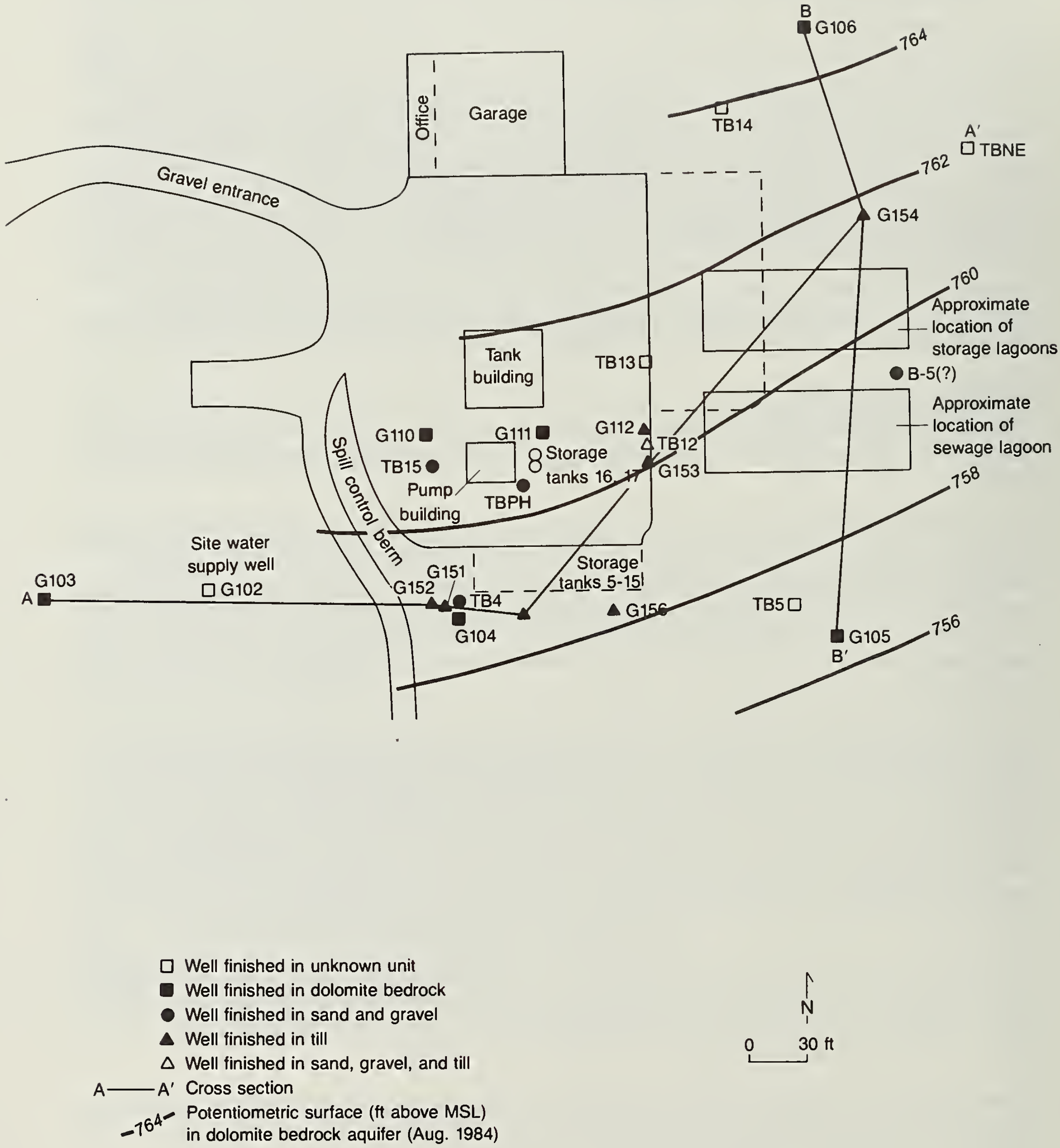

Figure 47 Map of Frink's Industrial Waste showing storage tank locations, approximate location of storage and sewage lagoons, well locations, potentiometric surface in dolomite bedrock aquifer, and lines of cross section.

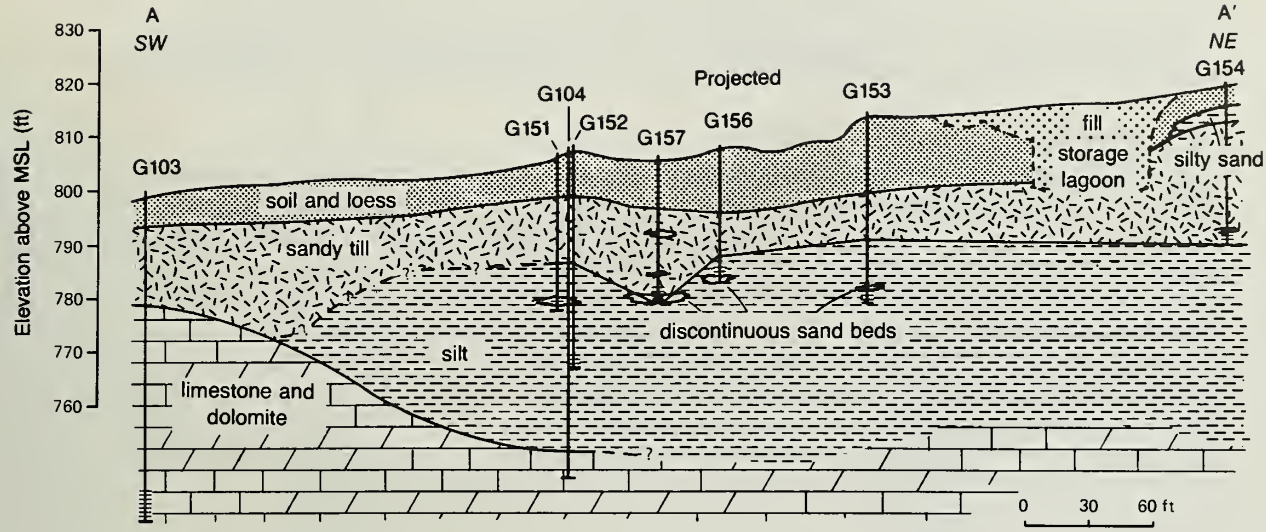

Figure 48 Frink's Industrial Waste cross-section A-A', southwest-northeast through center of storage lagoon and along southern boundary of site.

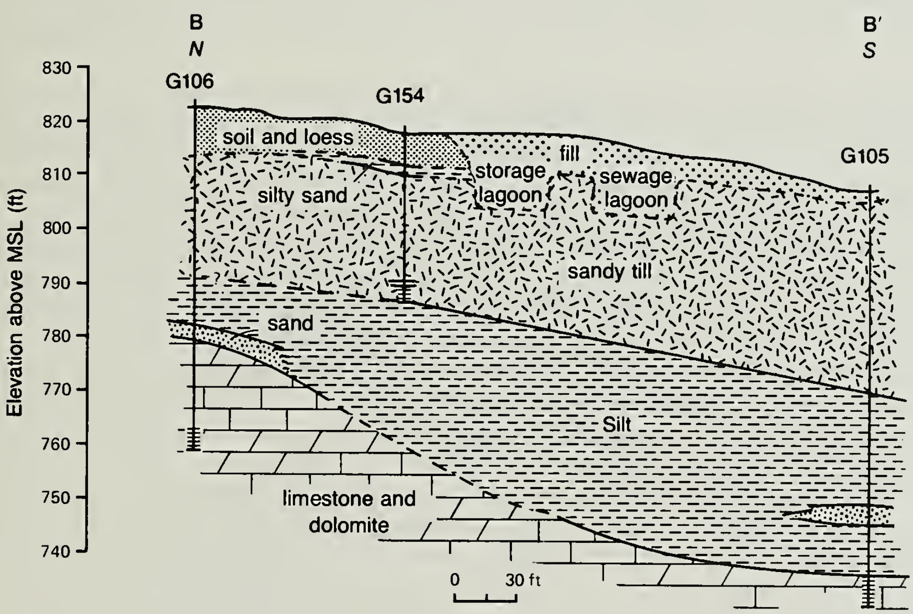

Figure 49 Frink's Industrial Waste cross-section B-B', north-south through center of storage and sewage lagoons.

Sandstones, and the Elmhurst-Mt. Simon Sandstones. Direct hydrologic connection exists between the Galena-Platteville Groups and the Ancell Group, which presents the potential for pollutants to contaminate both aquifer systems. In addition, contaminants may flow downward along uncased wells to the deeper Ironton-Galesville Sandstones and the Elmhurst-Mt. Simon Sandstones. Such inter-aquifer communication and contaminant migration is undocumented, however, due to the lack of data pertaining to deep groundwater flow.

Groundwater Monitoring History

Prior to 1982, only one monitoring well existed, which was approximately 170 feet south of the Frink's site. Characterization of the geologic conditions at the site was based on the driller's log of the water-supply well, which apparently was also used for monitoring. When IEPA approved a supplemental construction permit in 1982, it required the installation of four new monitoring wells (G103-G106). Three wells were installed along the southern boundary of the site and a background well was placed along the northern boundary (fig. 47). Each well was drilled to a depth of 60 feet. Three wells (G103, G104, and G106) were finished in the bedrock; the fourth (G105), in the overlying till. The fourth well was later redrilled and finished in the bedrock. In December 1983, the operator added three more monitoring wells at the request of IEPA. Two (G110 and G111) were placed in the bedrock and one (G112) was placed in the till. Finally, in November 1984, the IEPA installed seven monitoring wells (G151-G157) in the glacial drift.

With the exception of wells drilled by IEPA, information regarding monitoring well construction is sketchy. The data provided do not indicate the diameter, type of casing, nor screen specifications for most of the earlier wells. Also missing is information on well installation techniques, the method and increment of soil sampling, and the identity of the person who described the sample. The existing data indicate that the majority of wells installed by the operator appear to be improperly constructed. Many wells constructed prior to the installation of the IEPA wells have poor annular seals. This could allow hydrologic communication and possible contaminant migration from the ground surface to other geologic units. Figure 50 illustrates the differences between wells constructed by the operator prior to 1984 and those constructed by the IEPA in 1984. In addition to poor well construction techniques, poor sample descriptions in the driller's logs make it impossible to determine the geologic materials in which the previous wells were finished.

The 1982 discovery of organic contaminants in monitoring well G104 and subsequently in several domestic wells along Ferguson Road approximately 1/2 mile south of the site raised many concerns regarding waste operations and containment at the site. The operator contended that contaminants found in groundwater samples of monitoring well G104 had escaped from the sludge lagoon when the underlying "clay liner" was breached during soil sampling by the IEPA on June 24, 1982. They contended that organic contaminants, including trichloroethylene (TCE), flowed through sand and gravel lenses in the glacial drift to well G104, which apparently was improperly sealed (Bradbury, 1984). These contaminants, the operator indicated, then flowed down the annulus of the well into the dolomite bedrock. Analysis by ISGS geologists of soil samples from the "purported" clay liner beneath the lagoon, however, indicated that the material did not appear to possess very low hydraulic conductivity, which is desirable in a clay liner for a waste disposal site (ISGS, 1983). It is more likely that contaminants may have migrated southwest through the shallow unconsolidated groundwater system from the sludge lagoon during a period of years (i.e., from the time the lagoon became operative to when the wastes in the lagoon were excavated and removed from the site in 1982). Further evidence supporting the second theory comes from the analysis of soil and groundwater samples collected from monitoring wells G151to G157, constructed by the IEPA in 1984. Although soil samples were not contaminated, groundwater from these wells was contaminated with organic priority pollutants, including trichloroethylene. The extent of this contamination is unknown and, more importantly, the vertical flow paths through the shallow groundwater system to the dolomites can only be approximated. Presently, a vertical gradient through the glacial materials toward the dolomite bedrock is estimated to be 0.533 ft/ft, which was determined from a piezometer nest composed of wells G151 and G152.

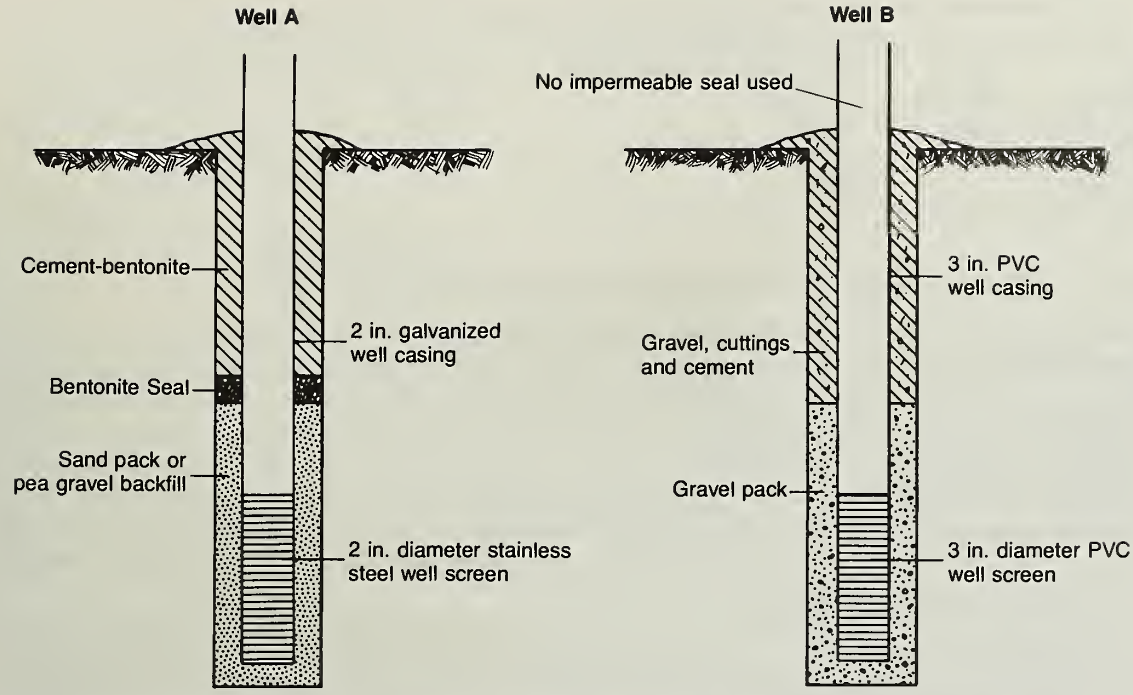

Figure 50 Typical construction of monitoring wells at Frink's Industrial Waste. Well A typifies wells completed by the IEPA; well B represents wells constructed by the site operator .

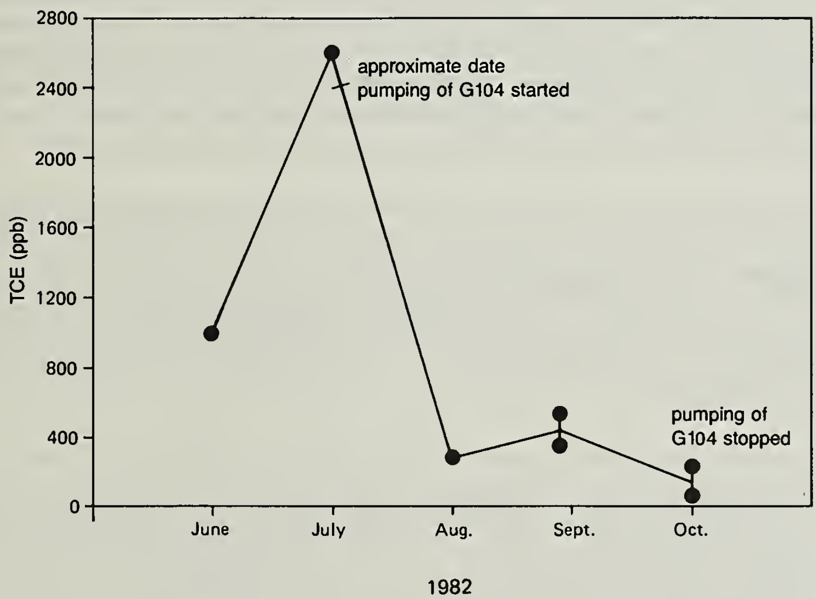

Figure 51 Concentration of trichloroethylene measured at Frink'sIndustrial Waste monitoring well G104 between June and October, 1982

Table 16 Parameters initially (1982) analyzed at Frink's Industrial Waste site

pH	Lead	Total organic carbon (TOC)
Cadmium	Mercury	Toluene
Chromium	Nickel	Xylene
Copper		Phenol
Cyanide		Zinc

Table 17 Parameters analyzed at Frink's Industrial Waste site during and after 1983

Arsenic	Cadmium
Chromium (total)	Cyanide
Lead	Fluoride
Manganese	Mercury
Nickel	Phenols
*pH (field measurement)	Silver
Zinc	*Total organic carbon (TOC)
*Total organic halogen (TOX)	*Specific conductance (SC) (field measurement)

*Four replicate measurements required.

Contamination of the shallow bedrock aquifer appears to have resulted primarily from two processes: contaminant flow through inadequate annular seals around wells such as G104 and contaminant migration through the shallow groundwater system (from the sludge lagoon through the overlying unconsolidated materials to the Galena Dolomite).

One step taken to reduce contaminant migration has been to reconstruct those monitoring wells which previously had poor annular seals. Wells G104 and G105 were reconstructed in late 1982 or early 1983. Groundwater from well G104 was also pumped through an activated carbon filtration system to remove contaminants, and then discharged at ground surface. Following this process, G104 showed trends of decreasing pollutant concentrations such as trichloroethylene (fig. 51). The results of this pumping program are not well understood because of limited data. Bacon (1985) suggests that groundwater pumping and discharge may have "confused the picture associated with the effort to identify the source of contaminants and perhaps contribute to spreading low level contamination further down gradient via the surface discharge routes."

The sampling and analysis procedures used to determine contaminant migration in the initial monitoring well (prior to 1982) are not reported. In 1982, the four new monitoring wells were sampled and analyzed for pH, total organic carbon, toluene, xylene, and nine other constituents (table 16). A year later, IEPA required the analyses to include pH, specific conductance, total organic carbon, total organic halogen, cyanide, fluoride, and nine metals (table 17). Well G104 was also sampled weekly for nine organics (table 18). This latter sampling was reportedly conducted according to IEPA procedures.

The most recent monitoring program proposes three levels of groundwater monitoring. During the first year, samples from 12 wells will be analyzed quarterly for pH, specific conductance, total organic carbon, total organic halogen, and a full scan of volatile organics to determine current background conditions. In the second year, samples from all wells will be analyzed quarterly for pH, specific conductance, total organic carbon, and total organic halogen, and semiannually for the full scan of volatile organics. After the second year of the detection monitoring program, samples from all wells will be analyzed quarterly for the indicator parameters, pH, specific conductance, total organic carbon, and total organic halogen. The samples from the bedrock monitoring wells will also be analyzed annually for the full scan of volatile organics.

Table 18 Parameters monitored weekly in well G104 at Frinks Industrial Waste site

Methylene chloride	Toluene
1,1-Dichloroethane	Xylene
trans-1,2-Dichloroethylene	Pentane
1,1,1-Trichloroethane	
Trichloroethylene	
Tetrachloroethylene	

Evaluation of Groundwater Monitoring Program

The initial groundwater monitoring program, which consisted of a single well, was inadequate for detecting contaminant migration and describing groundwater flow conditions at the site. The IEPA subsequently required additional wells to be installed. The geologic materials encountered in these well borings, installed by the operator in 1982 and 1983, were poorly described. In addition, the operator also failed to include important technical information pertaining to well installation and construction for the wells it installed. From available data, wells installed by the operator appear to have been improperly constructed.

In 1982, organic priority contaminants were identified in monitoring well G104 and, subsequently, in domestic wells along Ferguson Road 1/2 mile south of the site. Contaminants in groundwater of monitoring well G104 appear to have migrated from the waste lagoon through the shallow groundwater system and along annular seals of poorly constructed wells, such as G104, to the Galena Dolomite. Contaminant migration away from the site through the unconsolidated material may continue until a remedial action program is initiated. It is imperative that the bedrock monitoring program be upgraded. Present inadequacies in the monitoring program include: 1) insufficient monitoring of the dolomite bedrock downgradient of the Frink's site (i.e., between wells G104 and G105 and between wells G106 and G105; fig. 47); 2) insufficient bedrock monitoring downgradient of the waste lagoons, (fig. 47); and 3) insufficient data on groundwater flow, especially the components of vertical flow within the shallow groundwater system and the Galena-Platteville Dolomites. Groundwater and associated contaminants may be migrating downward to the Ancell Group (hydrologically connected to the Galena-Platteville Groups), as well as away from the site. Data on groundwater conditions at the site, however, do not permit a thorough understanding of groundwater flow and/or contaminant migration in the vicinity of the Frink's storage facility.

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CONCLUSIONS AND RECOMMENDATIONS

Groundwater monitoring programs at hazardous waste disposal sites have improved significantly in the past 10 years. Since RCRA was originally promulgated in 1976, information from the successes and failures of hazardous waste disposal activities has aided the improvement of subsequent groundwater monitoring programs. Much of the improvement in Illinois, however, can be attributed to the IEPA, which has more stringent requirements than RCRA.

Prior to the creation of the IEPA in 1971, little attention appears to have been paid to groundwater monitoring at hazardous waste sites. For the few sites that had groundwater monitoring programs, information about their programs, such as records of borings, well construction, and analytical procedures, were sparse or nonexistent. After IEPA came into existence, sites were required by permit to have groundwater monitoring programs.

The early (pre-RCRA) permits generally required only limited groundwater monitoring. Groundwater monitoring technology was in its infancy and research on groundwater contaminant transport was sparse, compared with current knowledge. Permits specified as few as two monitoring wells to as many as 14. The number of wells appears to have coincided with the number of wells proposed by the operator. Wells were typically constructed of PVC casing with solvent-cemented couplings, the least expensive materials available, and were monitored quarterly for as few as three parameters. Depths and well locations were seldom specified and records of the construction details for many of the first monitoring wells no longer exist. Overall, these programs were inadequate. For example, the Peoria Disposal Company site was required to have three groundwater monitoring wells. These wells were located in shallow sands on the west side of the site. Later information, however, showed these wells were located upgradient of the disposal area. Furthermore, these wells seldom yielded enough water for a valid sample.

Groundwater monitoring programs were greatly expanded after RCRA was implemented. RCRA required a minimum of four monitoring wells; one upgradient and three downgradient. Most hazardous waste sites already met this minimum requirement. Many newer sites proposed, and had accepted, groundwater monitoring plans that located one of the four required wells in each corner of the waste site. The new law provided a mechanism, however, for the IEPA to require more extensive monitoring programs. Site operators were required under RCRA to install new monitoring wells or to replace questionably constructed wells so that groundwater in the uppermost aquifer (as defined by RCRA) would be monitored downgradient of the waste disposal area. New wells were generally constructed using steel or threaded-joint PVC casing and screens, thus eliminating problems with PVC solvent-cement which contributes organic compounds to water samples. Records of borings, well construction techniques, and analytical methods also improved significantly and a greater number of chemical parameters were required to be analyzed.

The evolution of groundwater monitoring plans is continuing and programs are becoming more sophisticated. Many new wells are being constructed of stainless steel, which some researchers believe to be more suitable than PVC for monitoring organic compounds. Other research indicates that the two materials are equally suitable and, in some cases, that PVC may be better. Many wells now have dedicated sampling devices to eliminate the possibility of cross-contamination between wells during sampling. The list of priority pollutant chemical parameters analyzed is growing, and analyzing for a full spectrum of organic compounds is becoming common. In addition, the science of quantitative chemical analysis has improved so that contaminants can be detected in significantly lower concentrations.

Even as this study was being conducted, groundwater monitoring programs were changing at many of the selected sites. Some sites which had inadequate groundwater monitoring programs when the study began, now have adequate programs. Many are currently in transition due to recent closure, remedial actions, or application for a RCRA part B permit. None of the active

sites have yet received final part B approval, so they are currently on interim status. Because of these recent activities, the groundwater plans of these facilities are likely to continue to improve.

The ISGS research team view this trend toward more sophisticated groundwater monitoring programs as positive and believe the evolution will continue. The researchers offer the following recommendations:

- Thorough hydrogeologic studies are necessary before an adequate monitoring program can be established. The depths, extent, and hydrogeologic properties of the geologic materials comprising the shallow groundwater flow system, as well as the direction(s) of groundwater flow, must be understood to properly determine the placement of monitoring wells. This information should be obtained from detailed hydrogeologic investigations prior to design of the monitoring program.
- The design of a groundwater monitoring program should consider each disposal site individually. Monitoring should begin before the site opens to provide more reliable background water quality data. Those sites with complicated subsurface geologic conditions will probably require a greater number of monitoring wells. The minimum four wells required by RCRA is unlikely to be adequate for most disposal facilities. Waste disposal records at each site should be reviewed to ensure that proper indicator parameters are being tested.
- Technical topics such as casing material, well spacing, screen length, and indicator parameters need special attention. Although the US EPA recommends Teflon or stainless steel, recent research suggests these higher cost alternatives may not be necessary or desirable in all cases. Well-screen lengths greater than 10 feet should be used only where a thick deposit is being monitored or where water level fluctuations are large. Under no circumstances should well screens or their sand packs connect two permeable zones. Finally, research on well spacing is needed. One thousand-foot well spacings downgradient of a disposal area are probably inadequate. A consistent, reliable method of determining optimum well spacings is needed.
- The importance of good record-keeping cannot be overemphasized. Information and results from groundwater monitoring programs should be summarized periodically to permit efficient evaluation of monitoring programs and changes in site conditions. Currently, large volumes of data must be screened to piece together the geology and groundwater monitoring history of most sites. This present situation makes it is difficult, if not impossible, to fully determine the historical effects of a hazardous waste disposal site on groundwater.
- Greater use should be made of geophysics and other economical techniques for site characterization, and computer modeling for prediction of potential contaminant migration. New groundwater monitoring techniques should be explored. Geophysical techniques, which have under gone significant advances in the last several years, may be particularly useful in supplementing traditional monitoring plans, and in indicating where more wells are needed. Modeling, which incorporates preliminary data, also should be used to predict the extent of potential contaminant plumes and to determine well spacing and location.
- Because records documenting the monitoring programs of on-site waste disposers and generators of hazardous waste are scarce, greater attention should be extended to these facilities, many of which may pose a significant hazard. With the exception of the oil company impoundment sites, the IEPA computer files of facilities identified few on-site disposal operations receiving hazardous wastes and having groundwater monitoring programs.